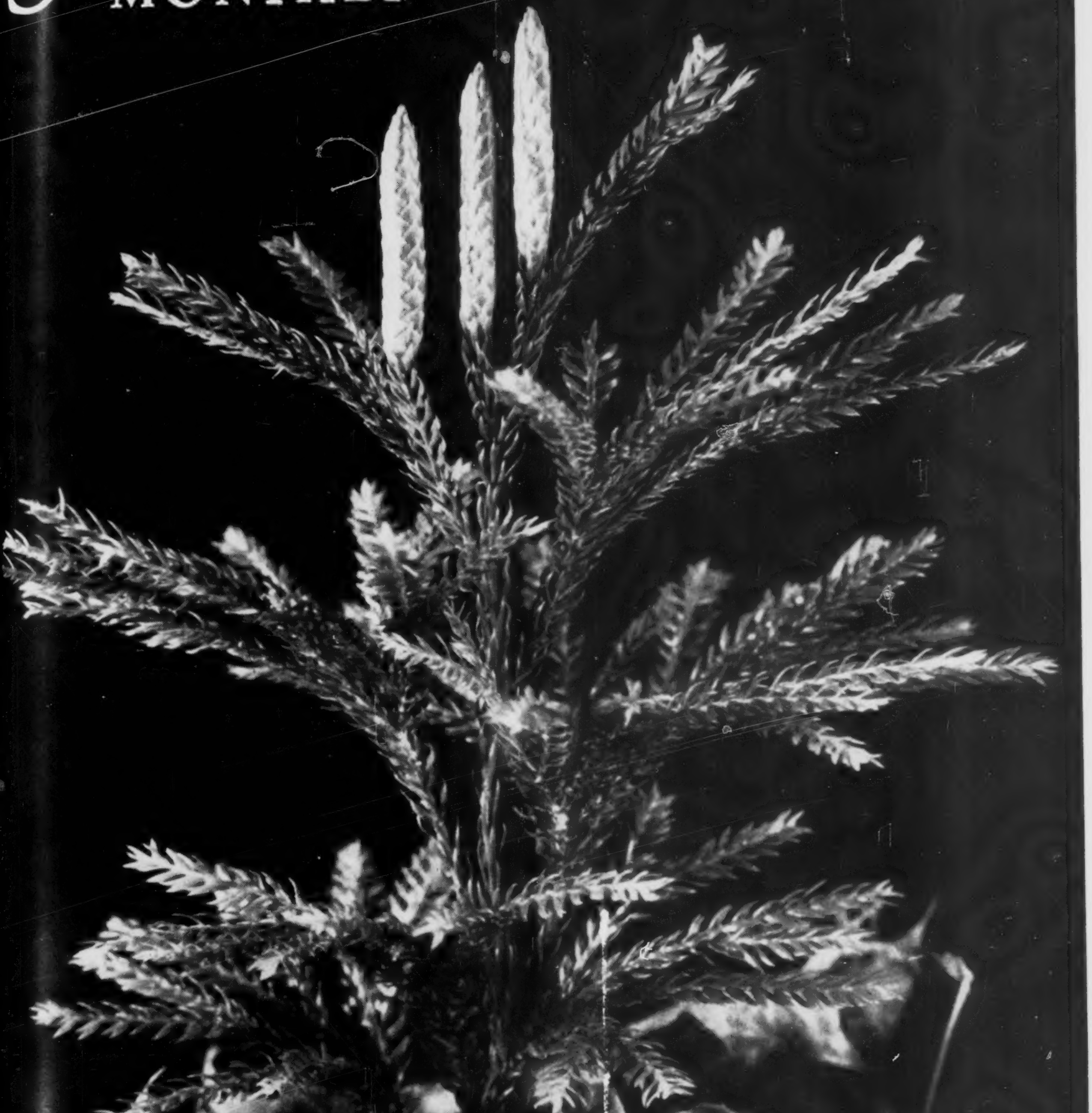
The SCIENTIFIC MONTHLY



VOL. LXXVII, NO. 6 DECEMBER 1953

THE SCIENTIFIC MONTHLY

VOL. LXXVII — DECEMBER 1953 — NO. 6

Index Issue

Annual Meeting, AAAS, Boston, Massachusetts, December 26–31, 1953

Established 1872 as *The Popular Science Monthly*; since 1915 an official publication of the American Association for the Advancement of Science.

Publication office, Business Press, Inc., 10 McGovern Ave., Lancaster, Pa. Orders for subscriptions and requests for change of address should be directed to the Circulation Department, A.A.A.S., 1515 Massachusetts Ave., N.W., Washington 5, D. C. Subscriptions: $7.50 per year; single copies 75 cents. Four weeks are required to effect change of address.

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 Entered as second-class matter at the Post Office at Lancaster, Pa., December 30, 1947, under the Act of March 3, 1879. Acceptance for mailing at the special rate of postage provided for in the Act of February 28, 1925, embodied in paragraph (d-2) Section 34.40 P.L. & R. of 1948. Indexed in the *Reader's Guide to Periodical Literature*. The A.A.A.S. also publishes SCIENCE. Subscription and advertising rates on request.

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Science and Technology

(From the Month's News Releases)

Projection Stand

A combination storage cabinet and projection stand has been designed for audio-visual equipment protection and portability. The unit is mounted on 3 in. ball-bearing swivel casters, ensuring complete mobility for movement of equipment. The all-metal unit includes ample speaker storage, a shelf for film and accessories, and a sturdy lock on the cabinet door. The top is of shock-resistant plywood, with surface area designed for dual projection. The stand is available in 34 lb. and 70 lb. sizes.

Aluminum Putty

Aluminum putty for sculptors and hobbyists models like clay and hardens into a solid piece without baking, flux or chemical treatment. It can be applied in ⅛-in. coats over rigid wire or hardware screen armatures, or thinned for coating wood, cardboard, plaster, leather, canvas, and metals.

Rodenticide

Anticoagulant type of rat killer has insecticidal and fungicidal activities. The lethal effect of these new rodenticides depends upon multiple feedings of small quantities consumed over a period of days, effecting a minimum hazard to humans, farm animals, and domestic pets. When placed in bait stations located where rodents are known to feed, the tasteless, ordorless baits are consumed regularly with no signs of bait shyness. Rodents continue to eat until they die. The anticoagulant action imparts to cereal baits important resistance to insect infestations and the onset of mold, making it possible to store baits for long periods of time with less possibility of contamination.

Trash Burners

A redesigned line of outdoor trash burners features improved draft control and newly engineered grates and base pans that permit faster burning of damp, green, or dry refuse and garbage. These burners eliminate the fire hazards of burning, blowing scraps and minimize smoke and odor. They have been judged safe to use as close as 10 ft. from garages and out-buildings.

Small Electron Microscope

A small electron microscope is suitable for analytical work in research, medicine, pathology, and biology. The instrument utilizes an electron-optical system that includes condenser, objective and projective lenses. Magnification is continuously adjustable between 1500 and 15,000 diameters. The resolving power is better than 100 angstroms under average operating conditions. The electron gun is self-biased, and is equipped with an emission meter. The electromagnetic deflection method is used for beam alignment and focusing is facilitated by means of a beam wobbler. Specimen carriers for ⅛-in. diameter grids and plates are available, and a specimen airlock is utilized to obtain quick working cycles. The operator is fully protected against radiation under all circumstances. The microscope is approximately 74 in. high, 37 in. wide, and 25 in. deep. The power supply is 220 volt, 50 or 60 cycles, and the power consumption is about 1 kw.

Washboard Glove

Light laundry can be done with a washboard glove. Made of vinyl resin-base plastisols, the glove has built-in washboard-type ribs that safely scrub nylon stockings, silk lingerie, gloves, baby clothes, and shirt cuffs and neckbands. The flexible glove weighs 4 oz., and can be folded and carried in a pocket or overnight bag. It is available in yellow, green, blue, and pink.

Cesspool Clogging

A single safe application of a new bacteria discovery prevents cesspool clogging the year around. Several new bacteria strains that continuously produce proteolytic enzymes are combined with a group of fat and carbohydrate splitting enzymes to prevent the excessive accumulation of organic waste. The product prevents undigested soil-clogging particles from reaching the surrounding absorption field. The bacteria are not affected by bacteria-destroying soaps or detergents. It is safe and easy to use and is not harmful to the plumbing, the cesspool, or the bacteria therein. It is available in quart cans.

Windshield Protector

A heavy plastic cover protects the windshields of parked cars from ice, sleet, rain, and frost. The cover, held in place by the car doors, can be removed quickly. The plastic will not tear or stick to the windshield and will resist cold as low as 60° below zero. The protector comes in a waterproof plastic bag, and can be stored in the glove compartment while driving.

Telephone Index

A new telephone index is designed to fit directly beneath the telephone, giving the impression of a single unit. When the alphabetical index cards are pulled out, the desired number is directly in front of the telephone. Dialing may be done one digit at a time, without having to memorize the whole telephone number. The index base is made of plastic, with non-skid feet making the phone secure at all times.

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THE

SCIENTIFIC MONTHLY

DECEMBER 1953

The Origin of Stars and Galaxies

D. TER HAAR

This paper by Dr. Dirk ter Haar, like his earlier one, "The Age of the Universe," [THE SCIENTIFIC MONTHLY, 77, 173 (1953)], is based on material which will appear in a critical and historical survey he is currently preparing. In this present paper he discusses five of the principal theories on the formation of stars and galaxies.

THE scientifically minded human being is not satisfied to observe that according to astronomers stars exist and can be found together in huge agglomerations called galaxies. He immediately asks: "How were these stars and galaxies formed? When were they formed? Are they still produced?" And so on. It is the purpose of the present paper to discuss in broad outline some theories which try to answer some of these questions. Such theories are called cosmogonies since they deal with the origin or genesis of our universe, and it must be regretted that so often the term cosmology is loosely used in this connection, since cosmology is a much wider term which is concerned with the study of all aspects of the universe.[1] General cosmogonies vary enormously in scope and purpose. Some of these theories discuss in detail the formation of stars and galaxies, whereas others are content to sketch the general framework in which the formation of stars and galaxies presumably take place without considering the actual formation in any detail. We shall be mainly concerned with the first kind of theory, while a recent monograph by Bondi[2] is mainly concerned with the second kind of theory which, moreover, often uses the whole arsenal of accessible general relativity, that is, general relativity applied to homogeneous systems.* The main theories which we shall discuss are (1) Jordan's theory of continuous creation, (2) Gamow's general discussion in connection with the α-β-γ-theory[4] of the origin of the chemical elements, (3) The Bok-Spitzer-Whipple dust-cloud hypothesis, (4) Hoyle and Lyttleton's accretion theory, and (5) von Weizsäcker's general cosmogonical ideas.

At this point we would like to remind readers of two facts which we mentioned in a recent survey in this journal.[5] The first one is that some of the brightest stars in our own Milky Way are using up their nuclear fuel so fast that they must have been created during the present epoch, that is, during the last few billion years.[6] The second fact is that there are a great many independent indications that about three billion years ago "something" happened, and that the universe as we observe it has existed in practically the same state for the last

* The restriction to homogeneous systems may well be a very serious one, as even the slightest inhomogeneity may change the conclusions reached for a homogeneous system.[3]

FIG. 1. The spiral nebula M51. (Photo by Mount Wilson and Palomar Observatories.)

three billion years, but that most probably the situation before that period was completely different.

Observational Data*

Before starting our main discussion of general cosmogonies we shall give a brief survey of the observational data which are relevant to our discussion. Our Milky Way is one of the many concentrations of stars in the universe known as *galaxies*. These galaxies, or *extragalactic nebulae* as they are sometimes called, occur in different forms. Some of them seem to be ellipsoidal, ranging from practically spherical nebulae to elliptic nebulae for which the ratio of the projected axes is as high as three. A second class are the so-called spiral nebulae which consist of a central nucleus from which spiral arms start (see Fig. 1). Our Milky Way is probably such a spiral nebula. A third class is that of the barred spirals. In their case, the spiral arms start at the end of a straight "bar" which extends across the nucleus of the spiral (see Fig. 2). Finally, there are the irregular nebulae which have no definite structure at all.

We may mention in passing that our sun is situated far outside the center of the Milky Way which is an extremely happy circumstance for, if we were situated in the center of our galaxy, the whole sky would be between ten and a hundred times as bright as the sky at full moon which would seriously interfere with astronomical observations in the photographic region.

* We have taken the material for this section mainly from an earlier survey article.[7]

Galaxies often occur in groups. Thus our own Milky Way is in fact a member of the so-called local group which contains at least three spiral nebulae, six elliptic nebulae and four irregular nebulae. Larger groups are known, however, and the so-called Virgo and Coma clusters (called after their position in the sky in certain constellations) contain about one thousand galaxies. The average size of a galaxy in such a cluster is probably that of our own Milky Way, that is, such a galaxy contains a few hundred billion stars and has a radius of a few ten thousands of light years.† The radius of a cluster of galaxies is of the order of magnitude of a million light years.

In many ways our Milky Way is a rather average galaxy, and for a description of smaller concentrations of stars and of matter in general we now turn to our own Milky Way. One must, however, bear in mind that other galaxies contain the same kind of mass concentrations. In our Milky Way we have many agglomerations of matter which are not stars. For our discussion we need be concerned only with those gas masses which have no direct connection with stars, the so-called interstellar gas clouds. Between the stars there exists a large amount of matter, mainly in the form of hydrogen atoms. The density of this interstellar gas is extremely small—there are only a few atoms per cubic centimeter.‡ However, owing to the large distances in our galaxy and especially between the stars (the average distance between two stars is of the order of a few light years), the total mass of interstellar gas is practically the same as the total mass of all the stars in the galaxy.

This gas is not evenly distributed between the stars. In places its density is between ten and a hundred times larger than the average. These places of higher densities are the so-called interstellar gas clouds. These clouds extend over tens of light years and their total mass is of the order of a few thousand times the mass of the sun. These clouds consist of two types, the so-called dark clouds and the so-called reflection or emission nebulae (Figs. 3 and 4). Figure 3 gives a picture of a part of the Milky Way which is obscured by such a dark cloud. In such a dark cloud small solid grains can form, the so-called smoke particles.§ Their presence is shown by their scattering properties. Their dimensions are of the order of the wavelengths of visible light, and

† One light year is the distance traveled by light in one year and is equal to six million million miles.

‡ Compare this with the more than ten billion billion molecules per cubic centimeter in ordinary air.

§ The term *smoke* was coined by the Dutch astronomer van de Hulst[8] to indicate the mode of formation of the solid particles.

they scatter blue light more strongly than red light, thus producing a *reddening* of the stars whose light reaches us through interstellar clouds.

The emission and reflection nebulae are gas clouds which are illuminated by neighboring stars. These stars excite the atoms, and they in turn emit radiation. Figure 4 shows such a nebula.

As far as extragalactic nebulae are concerned, elliptic nebulae do not contain interstellar clouds, but irregular nebulae and spiral nebulae do, the latter especially in their arms.

The stars in our galaxy themselves often occur in groups or clusters. The galactic or open clusters contain from a score to a few thousand stars and the distances between the numbers of such clusters are relatively large. On the other hand, the spherical or globular clusters contain at least fifty thousand stars which are very near together.

In this connection it is of interest to mention Baade's two star populations.[9] Baade found that, roughly speaking, most stars fall into two distinct groups, called stellar populations I and II. Population II contains stars like the sun which on the whole are found in the center of spiral nebulae or in elliptic nebulae and in globular clusters, and which generally rotate slowly.* Population I taken by and large contains stars brighter than the sun, which are found in spiral arms and open clusters. Their rotation is often fast.

Fig. 2. The barred spiral NGC 1300. (Photo by Yerkes Observatory.)

Fig. 3. "Horsehead" nebula in Orion. (Photo by Mount Wilson and Palomar Observatories.)

Continuous Creation?

Most general cosmogonies make the basic assumption that during the last few billion years, which is the period with which these cosmogonies are concerned, the laws of nature have been the same as we assume them to be at the present and that also the total mass of the universe has not changed during this period. In this case one is dealing with a more or less well-defined problem with well-defined rules which have to be observed during the solution. In Hoyle's theory of continuous creation of matter, however, one introduces necessarily more or less ad hoc† new concepts and one investigates their consequences.

Unfortunately the theories of Hoyle[10] and Bondi and Gold[11] are so bound up with general relativity that it is impossible to give a qualitative picture of these so-called steady-state theories beyond the remark that in these theories matter is created at all times. One might ask how it is possible to bring these theories, which have no definite "starting time" for the universe, in line with the great amount of evidence to the fact that about three billion years ago "something" happened.[5]

A cosmogony which to some extent is related to these theories is the one developed by Jordan,[12] in

* Our sun, although belonging to population II, is a slight exception in so far as it is not situated in the center of the Milky Way but well outside, a position which is not characteristic of stars of the spectral type of the sun.

† It is in this connection of interest that the term introduced by Hoyle in the equations of general relativity, which is responsible for the creation of new matter, was very carefully discarded by Einstein when he formulated these equations.

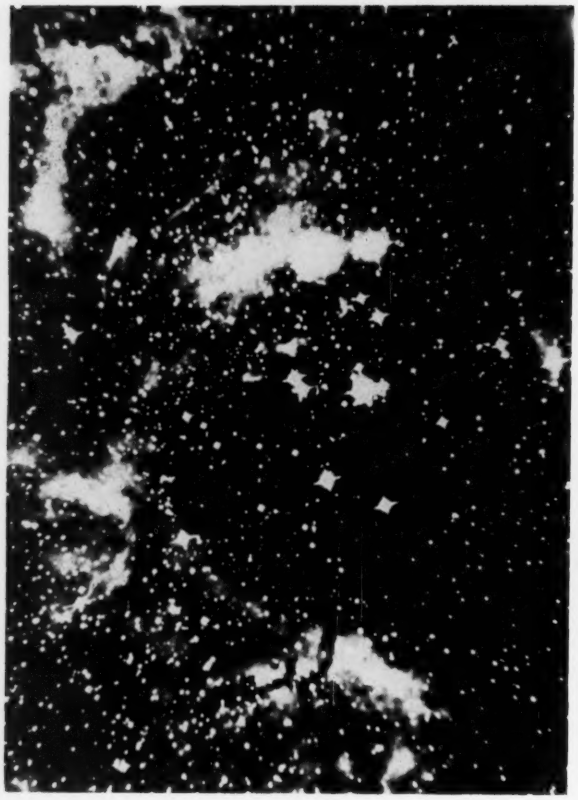

FIG. 4. The emission nebula 12 Mon. (Photo by Yerkes Observatory.)

so far as also in Jordan's cosmogony matter is created continuously, but in this case only for the last few billion years and not since time immemorial as in the steady-state theories. The starting point of Jordan's ideas are two papers by Dirac,[13] which we may discuss briefly.

Dirac notes that there is strong experimental evidence that the mass and charge of an electron, the velocity of light, the mass of a proton (or of a hydrogen atom), and the quantum of action are real constants, that is, are independent of time. Using these universal constants, we can construct by dimensional analysis an elementary unit of time.* If we divide the age of the universe by this unit we get a pure number, that is, a dimensionless quantity, which is very large, namely about 10^{40}, that is ten thousand billion billion billion billion.

Another dimensionless quantity can be found by taking the ratio of the electric force between a proton and an electron to the gravitational force between these two particles. Once again we get a large number equal to about 10^{40}. The fact that these two numbers which involve completely different quantities are nevertheless of the same order of magnitude led Dirac to the following principle. *"Any two of the very large dimensionless numbers occurring in Nature are connected by a simple mathematical relation in which the coefficients are of the order of magnitude unity."*

If one accepts the principle as fundamental, it follows that the gravitational constant should be inversely proportional to the age of the universe, since of the two large numbers which we discussed earlier the first one is proportional to the age of the universe and the second one inversely proportional to the gravitational constant.

By a similar argument Jordan shows that (1) the total mass of our universe is proportional to the square of the age of the universe and that (2) its radius is proportional to the age itself (expanding universe!).†

Having arrived at an increasing mass of the universe, Jordan continues his considerations by discussing the formation of stars. This part of his cosmogony is rather sketchy and open to criticism, but certainly provides a fascinating speculation on the formation of stars. Jordan assumes that stars are born spontaneously (*Spontanentstehung*) and shows that a spontaneous birth of matter will lead to bodies with masses of the order of magnitude of the solar mass, provided this creation leaves the total energy of the universe zero. The birth cries of such new stars are identified with the so-called supernovae. A supernova is a star which suddenly produces an enormous brightness—much larger than the brightness of an ordinary star like the sun.

Gamow's Cosmogonical Ideas

Gamow, Alpher, and Herman[4] have developed a detailed theory to account for the fact that so many different chemical elements exist. In their theory, which we cannot discuss here, they assume that about three billion years ago the density of our universe was much higher, its decrease being due to the expansion of the universe, which is governed by the equations of general relativity. During this expansion density fluctuations may occur and these may lead to "condensations," that is, a region of slightly higher density may retain this higher density or even increase its density, so that the universe which originally was homogeneous will become inhomogeneous and populated by mass concentrations. These mass concentrations are

* This unit is the time light takes to travel a distance which is equal to the so-called classical electron radius.

† It is interesting to note that if these relations are true the total kinetic energy and the total potential energy (which has a negative sign) of the universe are approximately equal, so that one is tempted to assume that the total energy content of the universe is exactly equal to zero.

the so-called proto-galaxies, that is, from them the galaxies are developed.

A formation of mass concentrations from density fluctuations is called the process of *gravitational instability*.[14] One can see how it can become important. A mass of gas will expand into space, if its temperature is so high that the kinetic energy of the gas particles is larger than their potential energy in the gravitational field of the gas mass itself.* The larger the total mass, the larger are its retentive powers, but small masses will disperse. Gamow[15] has shown that the smallest gas masses which can form a stable concentration of mass are of the right order of magnitude, that is, of the order of the mass of our Milky Way. He has not, however, developed this cosmogony any further and, for instance, has not considered the formation of stars.

The Dust-Cloud Hypothesis

We mentioned earlier that some interstellar clouds contain small solid particles, the so-called smoke particles. These smoke particles will be subject to radiation pressure from the star. In the same way as the bombardment by gas particles on a wall of a container produces the ordinary gas pressure, the bombardment by light quanta will produce the so-called radiation pressure. In most circumstances radiation pressure is much smaller than gas pressure, but in interstellar space, the density of the gas is so small that radiation pressure will become important. The first effect of radiation pressure on smoke particles is that it will blow together smoke clouds, that is, interstellar clouds containing smoke particles, to form regions of much higher density.[16] Such regions of high density can sometimes be seen as small globular dark objects, and some of them have been studied by Bok,[17] who sees these as the first stage of star formation. The further development of such dark clouds has been studied by Whipple[18] and Spitzer.[19]

This development takes place in three stages. In the first stage the radiation pressure continues to sweep smoke particles together. Figure 5 shows how this may happen. Smoke particle I will cut out some of the radiation which otherwise would have fallen on particle II from the left. This shadow effect will have as a result that the radiation pressure on particle II will not be uniform, but will have a resultant component in the direction of particle I, thus pushing particle II toward par-

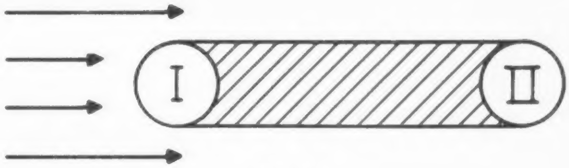

Fig. 5

ticle I. This "mock gravity" force, as it is sometimes called, will in the first stage of the development of the dark clouds be much larger than the gravitational force between the two particles. As a result the smoke particles in the dark cloud will "gravitate" toward the center.

The first stage will end when the cloud has become opaque to stellar radiation. The concentration will slow down until in its last stage gravitational capture by the central mass conglomeration will again produce a fast increase in mass.

Although on the one hand the theory leads to mass concentrations of the right order of magnitude, that is, with masses of the order of the solar mass, and on the other hand dark clouds such as occur in this theory have been observed, there are many reasons why one must be extremely wary in accepting the smoke cloud origin of stars as the only, or even the predominant, method of star formation. It seems far more likely that the processes studied by Whipple and Spitzer will play an important role in a more general cosmogony such as the one presented by von Weizsäcker, but that by themselves they very seldom will lead to the formation of a star. Some of the reasons for this statement are the following ones, first given by Whipple. A quantitative analysis of the process shows (1) that relative velocities in the cloud must be extremely small since otherwise the process will first of all be retarded and secondly is likely to become impossible because of increasing rotation of the proto-star† and (2) that it is doubtful whether the brightest stars in our galaxy can be produced in this way.‡ How far these difficulties can be surmounted by taking into account the influence of electromagnetic fields, as suggested by Spitzer, remains to be investigated.§

* Compare a similar situation arising in the case of planetary atmospheres. The moon could not retain an atmosphere, since its mass and hence its gravitational field is not sufficiently large.

† Since angular momentum must be conserved, the rotation of the cloud will increase during its contraction. This will lead to large centrifugal force which will act against the forces producing the concentration of matter toward the center.

‡ As soon as the central mass begins to resemble a star, it will also begin to radiate and the ensuing radiation pressure will prevent a further agglomeration of mass.

§ In a different connection it has been suggested[20] that such effects can be important in the slowing down of stellar rotation.

The Accretion Theory

Just after the war, Hoyle[21] also investigated the possibility of the formation of stars from the interstellar gas. To a large extent his considerations are complementary to those of Whipple and Spitzer, and we shall therefore discuss them separately. As Hoyle does not take into account the influence of turbulence in the interstellar medium, many of his conclusions must be revised, if not qualitatively at least quantitatively.

Hoyle's investigations fall into several parts. First of all, he shows that the interstellar gas substratum in a galaxy will be concentrated to the equatorial plane of the galaxy, that is, the plane through the center perpendicular to the axis of rotation.* From the observational data about the total mass of a galaxy and its mass distribution, Hoyle is able to estimate the density of the interstellar medium in an average galaxy such as our Milky Way. He then considers the evolution of a region where the density is accidentally higher than the average density, in much the same way as Whipple starts his considerations. Hoyle shows that the larger the mass of the proto-star, the faster *the rate of concentration toward the center* will be. However, this will mean that large mass concentration will stand a very large chance of being disrupted by rotational instability. We can see this as follows. A large concentration of mass at a certain distance from the center of the galaxy will usually be rotating because the parts nearer to the center of the galaxy will move around this center at a higher angular velocity than those parts which are farther removed.† This means that the cloud possesses angular momentum, which must be conserved during its contraction. This conservation can be attained only if the mass increases its rate of rotation and, in turn, this can happen only as long as the centrifugal force due to this rapid rotation is smaller than the gravitational force which is holding the mass together. For large masses the concentration is so fast that the centrifugal forces will, indeed, in most cases break up the proto-star before a real star is born. Hoyle sees this as the reason that in our galaxy most of the stars are smaller than the sun and that very few are larger.

In the case of smaller proto-stars, the concentration is much slower, and Hoyle considers it possible that the proto-star while moving through the galaxy can sweep up a sufficiently large amount of material without angular momentum to counteract the centrifugal instability and at the same time to provide most of the matter of the final star.‡

In this framework Hoyle and Lyttleton[22] have also considered the formation of binaries. They suggest that binaries are formed through chance encounters between two stars whose mean distance apart is decreased through accretion of interstellar matter.

von Weizsäcker's General Cosmogony

If we do not wish to leave the realm of present-day physics, as is done by Jordan, and at the same time wish to consider cosmogony in the framework of classical physics, that is, without using general relativity, we still can arrive at a picture of the formation of stars and galaxies. This was recently shown by von Weizsäcker,[23] who drew attention to the importance of turbulence and rotation in our universe. As we think that his considerations are probably the most worth while of all recent general cosmogonies, we shall discuss his ideas in slightly more detail than we have done with the other cosmogonies.

As working hypotheses von Weizsäcker uses the following assumptions. (1) Stars and galaxies have been formed during the present epoch, that is, during the last few billion years, and are still being formed. (2) All the laws of physics have been the same as at present during that period. (3) The gas filling the universe was, and is, composed of the chemical elements with the same relative abundances as we find at present.§ (4) Different parts of the gas had large relative velocities. von Weizsäcker assumes that one must look for the origin of these relative velocities which may according to him be connected with the expansion of the universe to periods before the present epoch. Gamow,[25] on the other hand, has remarked that the possibility that our universe as a whole is rotating should not be excluded a priori. This rotation might thus be the reason for the initial turbulence.

von Weizsäcker starts his considerations by dividing all celestial bodies or collections of bodies into three groups according to their degree of

* Hoyle actually finds a concentration toward this plane which is much stronger than the concentration of the stars in the galaxy, but this conclusion seems to be no longer valid, if turbulence is taken into account.

† Compare similar considerations in the discussion of the age of star clusters.[5]

‡ This last conclusion of Hoyle's seems to be rather ill founded. A quantitative analysis of the process seems to indicate that accretion can account only for a very small proportion of the mass of the final star.

§ This hypothesis is really irrelevant to von Weizsäcker's discussion, and it can be shown[24] that it is probably not a necessary assumption either as there are probably processes in nature which have been active during the present epoch and which will produce a relative abundance distribution of the chemical elements such as we find at present.

rotational symmetry. Group I comprises those structures which show spherical symmetry; these structures are either non-rotating or very slowly rotating. Group II contains all structures with rotational symmetry. The irregular bodies form group III. Typical examples of group I are the spherical star clusters, stars like the sun and smaller (Baade's population II), the earth, and the other planets. Typical examples of group II are the elliptic and spiral nebulae, the bright stars (Baade's population I), binary systems, planetary systems,* satellite systems, and Saturn's rings. Irregular nebulae, star clouds, open star clusters, and interstellar gas and smoke clouds belong to group III. All the systems in group III show "cloudiness"; some of the systems in group II show cloudiness, but others do not; none of the systems in group I is cloudy. This cloudiness points to turbulence, as can be seen from the following. Cloudy structure means fluctuations in density and hence in pressure. Thus currents will be set up to counteract this cloudiness, and it is only possible to retain a cloudy structure, if the currents correspond to a turbulent state, since otherwise the situation would approach an equilibrium condition where there are no density fluctuations—hence no cloudiness. It turns out that one can also conclude from dimensional considerations that systems in which interstellar gas is present will be in a turbulent state.† However, one can show that a system such as a spherical nebula, which does not contain any interstellar gas but only stars, will not show turbulence.‡

Let us now consider the development of a universe filled with a turbulent gas. Owing to the turbulence, some eddies, or turbulence elements, will be regions of slightly higher density and may act as a potential hole, or trap because of the slightly larger gravitational field strength inside. Particles entering this potential hole will gain energy because of the difference in gravitational field strength. This gain of energy should enable these particles to leave the turbulence element again, were it not for the interaction with the material in the element through which they will lose their excess energy.§ It thus seems possible that such a turbulence element may grow in mass, and that in this way the universe may be divided into many rotating subsystems which we shall call proto-galaxies.

Inside such a proto-galaxy there are again turbulence elements, and a process similar to the one leading to the proto-galaxies may take place, leading to smaller rotating subsystems, say proto-clusters. This process will go on repeating itself as long as turbulence exists inside the proto-bodies, and in successive steps proto-stars, proto-planets, and proto-satellites may be formed.

One must bear in mind, of course, that the picture given here is extremely simplified. In reality there may be many more steps, and the steps will proceed simultaneously and more or less independently. One of the intermediate steps may, for instance, be the formation of proto-clusters of galaxies corresponding to systems such as the Virgo cluster.

Before we discuss the further development of such rotating proto-systems we may consider in slightly more detail the formation of the sequence of proto-systems of decreasing size. In general, we may expect that the linear dimensions of a turbulence element will be about an order of magnitude smaller than the dimensions of the whole system. The mass of a proto-system will then be smaller than the mass of the preceding proto-system by at least a few orders of magnitude, say, by a factor of about a hundred to a thousand. This mass ratio will be preserved, if in the subsequent developments essentially the same fraction of the mass is lost. It is therefore perhaps not irrelevant that a cluster of galaxies contains about one thousand galaxies, that a galaxy contains about a million times as many stars as a star cluster, and that a star cluster contains about a hundred thousand stars,‖ and that the sun's mass is about one thousand times the mass of Jupiter, and Jupiter's mass about ten thousand times that of its largest satellite.

* Although the sun, the earth, and other planets themselves belong to group I, since they are practically speaking spheres, the planetary system taken as a whole has only rotational and not spherical symmetry and thus belongs to group II.

† One must calculate the so-called Reynolds number, which is a dimensionless quantity measuring the ratio of the shearing forces due to velocity differences and the viscous forces which tend to level out velocity differences. If the Reynolds number is larger than a certain critical value, turbulence will occur, but if it is smaller than its critical value, the movement will be laminar, that is, smooth.

‡ Such a system can be compared to a so-called Knudsen gas. The mean free path of the stars, that is the distance over which a star will travel before it encounters another star, is large compared with the dimensions of the system.

§ Compare a similar situation which arises in the formation of the compound nucleus in nuclear reactions where the incident particle also loses its excess energy through interactions with the nucleons in the target nucleus.

‖ If we should take our rule of a factor of a thousand between successive stages to be universally valid—for which there are no good reasons—we should expect that between a galaxy and a star cluster, and between a star cluster and a star, a system is missing.

A completely simultaneous formation of all proto-systems will, however, not be realized. The size, and thus the mass, of the smallest turbulence element is determined by the density in the system.[26] Taking for the density the overall density in our universe we find for the mass of the smallest turbulence element a mass of the order of magnitude of the mass of our galaxy. Inside the proto-galaxy the motion will not be turbulent, but laminar. In this picture we get thus the simultaneous formation of proto-clusters of galaxies and proto-galaxies, but not of proto-clusters, proto-stars, and so on. These will be formed only as soon as the density through concentration of matter has sufficiently increased to allow turbulence to be set up inside the proto-galaxy. When the density has reached a value equal to the present density in our galaxy, the smallest turbulence element has just about the mass of a star cluster. The mass of a star is reached for densities such as are found in dense interstellar clouds, and so on.

Let us now consider the development of a rotating proto-system. The rotation of a system is the remnant of the angular momentum of the turbulence element. The only rotational motion of a gaseous system which does not consume energy through viscous interaction is the rotation of a rigid body where all points have the same angular velocity. The loss of energy, which as we shall see presently entails dissipation of the system, will cease only when the state of rigid rotation has been attained. However, a free gas mass, such as a proto-system will be, will not rotate rigidly, since the rotational velocity will be determined by the gravitational field. In general, in a proto-system there will be a concentration of mass toward the center, and the rotational velocity will decrease with increasing distance from the center. Also, the centrifugal forces which are acting on a rotating mass will tend to flatten the system, and it can be shown that, indeed, a proto-system will have a lens rather than a spherical shape corresponding to the observed shape of most galaxies.

Once some concentration toward the center has taken place, subsequent developments will accentuate it. As the velocities decrease when we move away from the center, the outer regions will try to slow down the inner regions through viscous interaction. This will result in two concomitant effects. (1) The rotation of the central part will be decelerated, thus decreasing its angular momentum and postponing the moment at which rotational instability will occur. (2) Part of the outer mass will fall into the center, thereby gaining sufficient gravitational energy to allow other parts to disappear from the system, taking with them angular momentum.

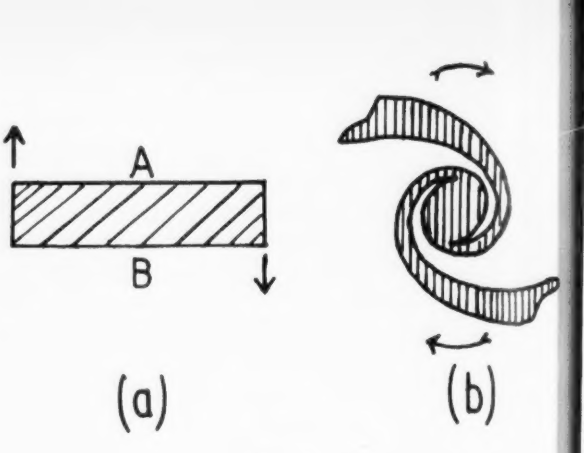

Fig. 6

One can ask how long it will take a system to become reduced to its central concentration. von Weizsäcker[23] has shown that this period is essentially equal to the time it takes a turbulence element in the system to wander from the edge of the system to its center. This same period is also approximately the time during which the proto-system will lose most of its rotation. If this period is long compared with the length of the present epoch, which is a few billion years, the system will not yet have lost much of its rotation, and we shall call it a *young* system. If, on the other hand, the period is small compared with the length of the present epoch, the system will have lost most of its rotation, and we shall call such a system an *old* system. We have thus found a first criterion for the age of a system. *The faster the rotation, the younger the system.* Of von Weizsäcker's three groups of systems mentioned a little while ago, group I contains the oldest and group III the youngest objects. We must emphasize that the age of a system as defined here is measured in its own time scale. Of two systems which were formed at the same time, one may be young and the other old. Some systems age more rapidly than others, so to speak, and the rate of aging is determined by the rate of dissipation.

As far as extragalactic nebulae are concerned, von Weizsäcker[23] has shown that both the criterion of rotation and the criterion of the ratio of time of dissipation and length of the present epoch lead to the conclusion that spherical nebulae are the oldest, the elliptic nebulae come next, then the spiral nebulae and finally the irregular nebulae.*

* It is amusing to note that owing to now obsolete ideas of the evolution of extragalactic nebulae, elliptic nebulae are called early type galaxies, and spiral and irregular nebulae late type galaxies, since it was assumed that elliptic nebulae would develop into spiral nebulae.

Another criterion for age is the absence or presence of interstellar gas. In the early stages of the evolution of a galaxy interstellar gas will be present, and stars with extended envelopes will continually interchange matter with their surroundings.[27] In later stages, however, all or practically all of the gas will have disappeared from the system or have been swept up by the stars. This criterion also indicates that elliptic nebulae are old and irregular nebulae young systems.

We may mention here that the spiral structure of galaxies easily follows from the rotation of an irregular cloudy system.[28] To illustrate this we have drawn Fig. 6. Part (b) of this figure shows the result of a rotation of a rectangular mass (a), if the angular velocity decreases with increasing distance from the center. The situation (b) is reached after the points A and B in (a) have completed one complete revolution around the center and the formation of two spiral arms is clearly shown.

Let us now consider the age of stars, again, of course, with respect to their own time scale. We saw earlier that bright stars, the so-called early type stars, are on the whole rotating at a fast rate, while the not so bright stars, the so-called late type stars, show little or no rotation.* We may thus conclude, and this conclusion is borne out by a further discussion as we shall see, that early type stars are young, and late type stars old.

If our classification of stars is correct, we should expect early type stars to be found mainly in spiral and irregular nebulae, while the nuclei of a spiral nebula and elliptic nebulae should contain mainly late type stars. This is, indeed, the case. Furthermore, spherical or globular star clusters contain mainly late type or old stars while open clusters contain young stars. This again is in agreement with the general picture that group I should contain old systems and group III young systems. Finally, we may remind ourselves that the luminosity of early type stars is so great that they are using up their nuclear fuel so fast that their lifetime can be only a few million years, whereas late type stars have a much smaller energy output.[5, 6] Once again we are led to assign the label "young" to the early type stars and the label "old" to the late type stars. We see thus that the various age criteria form a consistent set and that in general it is possible to assign uniquely a system to an old or a young group.

We may remark here that if stars are formed from proto-stars which are turbulence elements in a turbulent proto-galaxy, we should expect a correlation between the mass distribution among the various types of stars[30] and the mass distribution among the various sizes of turbulent eddies.[32] Such a correlation does, indeed, exist.

In conclusion we may consider briefly the fate of the early type stars. We saw that, on the one hand, they were rotating rapidly and, on the other hand, they were using up their hydrogen, which is their nuclear fuel, at a fast rate. One might ask what will happen first. Will they lose their rotation before exhausting their hydrogen, or will they exhaust their hydrogen before their rotation has disappeared? von Weizsäcker concludes that both cases are possible. In the latter case the star will first contract after its hydrogen is exhausted, in order to obtain the energy which it is losing through radiation from its own gravitational field. This contraction will proceed only as long as the centrifugal force at the equator of the star due to its rotation is smaller than the gravitational force. Because of the conservation of angular momentum the centrifugal force will increase during the contraction and an explosion may take place.† This explosion might well be similar to the so-called supernova phenomenon where a star is suddenly seen to increase its luminosity enormously. It is also possible that during the explosion heavy nuclei are formed, since the density in the star just before the explosion may well be of the order of nuclear densities and thus sufficiently high for the formation of heavy nuclei. A detailed discussion of this process would, however, lead us too far, and we therefore refer the reader to the literature.[4, 7, 24, 33]

If stars lose their rotation before exhausting their hydrogen they will not die young, but become old stars, that is, they may become late type stars. We may briefly consider how stars can lose their angular momentum.[20] The following mechanisms have been suggested: (1) accretion of matter with zero angular momentum, (2) slowing down of the rotation through viscous interaction inside the protostar, (3) electromagnetic braking, and (4) the formation and shedding of extended gaseous shells. von Weizsäcker considers the last mechanism to be

* We refer the reader to Struve's work[27, 29] for a thorough discussion of stellar rotation and its cosmogonical significance.

We restrict ourselves in our discussion to the so-called main sequence stars. The main sequence stars form about 95 per cent of all stars in the neighborhood of the sun.[30] Of the remaining 5 per cent about 1 per cent is giants, about 3 per cent white dwarfs, and about 1 per cent subdwarfs. We refer the reader to astronomical textbooks such as Russell, Dugan, and Stewart's[31] for a discussion of the various types of stars. As far as our discussion is concerned, early type stars coincide with Baade's population I and late type with his population II.

† It must be remarked that the contraction is a rapid dynamic process and not a slow development through equilibrium configurations.

responsible for the slowing down of the rotation, but the process cannot easily be analyzed quantitatively, and it remains therefore at the moment an open question whether or not this mechanism can be sufficient. We mentioned earlier that the total amount of material captured by accretion is much smaller than the original mass of the star, and it follows that in that case the angular momentum cannot appreciably be changed during the lifetime of an early type star. The second mechanism is also insufficient, as one can show by a quantitative analysis, and one is led to investigate electromagnetic processes of the kind suggested by Alfvén.[34] We assume with Blackett[35] that a rotating star will also possess a magnetic moment and we consider the influence of the magnetic field of the star on passing interstellar clouds. The radiation from the star will ionize the atoms in the cloud and owing to the magnetic field of the star ion currents will be set up in the cloud. These currents will tend to slow down the rotation of the magnetic field, that is, they will reduce the rate of rotation of the star. A rough calculation of the accumulative effect of encounters with interstellar clouds leads to the very tentative conclusion[20] that this electromagnetic effect may well have produced the slow rotation of late type stars.

In summarizing we may say that there have been lately a number of attempts to produce a general cosmogony and that probably von Weizsäcker's ideas have the best chance to lead to a more detailed understanding of the formation and evolution of stars and galaxies. It must, however, also be stressed that this cosmogony is only in its early stages and that of most of the processes only an overall picture has been given, while a detailed analysis has not yet been made.

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Homeostasis Versus Hyperexis: or Saint George and the Dragon*

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OF the terms in this title, homeostasis is one that you know about. Hyperexis is new, a word that comes from the *Timaeus* of Plato: I will have more to say about it later. Saint George and the Dragon is a bit of obvious imagery.

Homeostasis

There is a remarkable book, published twenty-odd years ago, called the *Book of Christopher Columbus.*[1] The author was Paul Claudel. It is at once a picture book, a play, a history, and an allegory. There is one scene in it where Columbus is being brought back to Spain, this time as a prisoner in chains in the ship's hold, because he had failed to find the gold of the Indies which he had promised. With him is the Ship's Cook, a friendly fellow. Columbus has been boasting of his prowess. The Cook says: "Are you to make a new heaven and a new earth?" Columbus says, "My business is not to remake the world but to discover it." The Cook says, "The world is wicked." Columbus says, "So much the worse for it, then, for I shall unveil it."

The notion which I should like to convey in this paper has to do with biological wickedness as applied to man. It is my thesis that in our thoughts about living processes, even in spite of our constant preoccupation with disease, we still give too much credit to the powers of good, and too little to the powers of evil, anthropocentrically speaking: too much, that is, to living and recovery, and too little to dying and death-dealing influences.

More specifically, I argue that the concept of homeostasis, as developed by Walter Cannon, useful and sound though it is, has now too strong a hold upon us, so that it seems almost to have possessed all our physiological thinking. Other balancing concepts are needed.

From much of the physiological talk that one hears, one might think that the Saint George of homeostasis always prevails, and that the dragons of disease are always in the end destroyed.

One should appreciate, from the beginning of our argument, that the notion of homeostasis, as developed by Cannon, was intended to have a broad meaning and broad implications. After defining homeostasis as the maintenance in the animal body of steady states, by coordinated physiological processes, Cannon[2] goes on to say (*Wisdom of the Body*‡), "It seems not impossible that the means employed by the more highly evolved animals for preserving uniform and stable their internal economy (i.e., for preserving homeostasis) may present some general principles for the establishment, reg-

* Paper read at a meeting of the Practitioners' Society, New York City, December 12, 1952. Some changes have been made from the paper as originally given.

† The writer wishes to express his indebtedness and gratitude to Alfred R. Bellinger for suggesting the passage in the *Timaeus*, and for some greatly valued criticism; and to Harold G. Wolff and Rene Dubos (members of the Practitioners' Society) for information and helpful comment about Claude Bernard.

‡ Page 24.

ulation, and control of steady states, that would be suggestive for other kinds of organization—even social and industrial—which suffer from distressing perturbations."

It is of interest to inquire what are the origins of the attitude represented by this term homeostasis.

In searching for the beginnings of an idea, one can go into history as remotely as one pleases, and find some sort of analogy almost as far back as the written word can be traced. To my eye, however, the climate in which the atmosphere of homeostasis first appeared was the eighteenth century. I am now thinking of the implicit attitude rather than the explicit idea. Whitehead has said[3] that the Middle Ages were the Age of Faith, based on reason, the eighteenth century the Age of Reason, based on faith. The faith of the eighteenth century was indeed boundless, faith in a rational plan of the universe, presided over by a beneficent Deity. If philosophers would just get their heads together, so they opined, this plan could be understood, and everything worked out to the best interests of all. Voltaire[4] poked his long satiric finger at them, but their faith was unshaken. If everything was not yet for the best, in the best of all possible worlds, it soon would be.

"Life, liberty, and the pursuit of happiness." Was there ever a fine phrase more completely indigenous to the century of its origin? As if happiness were ever attained by pursuit. But one should not press this too closely. As a preamble the phrase is magnificent. The trouble is, it soon became a philosophy.

With the nineteenth century, the moralists, the poets, and others, found increasing difficulty with the mechanistic approach, but in the sciences, determinism pursued its way triumphant; and why should it not have done so, considering the vast achievements derived therefrom? In most of the sciences the same philosophy still prevails, though in physics, if I understand rightly, strict mechanism has faltered somewhat of late, and natural philosophers are no longer secure. It is not our purpose, however, to pursue this, even if we could, but to concentrate on one aspect only of this historic trend.

Halfway between the end of the eighteenth century and the present day rises a gigantic figure, perhaps the greatest of all physiologists, Claude Bernard. It was by him, as everyone knows, that the general concept, of which homeostasis is one immediate descendent, was explicitly declared.

Bernard[5] had no doubts about the validity of determinism in science nor about the central place of physiology in its study. "There is," said he, "an absolute determinism in every phenomenon of life." He continues, "General physiology is the fundamental biological science, toward which all others converge. Its problem consists in determining the fundamental conditions of life's phenomena. Pathology and therapy rest equally upon this common base. It is by the normal activity of organic elements that life manifests itself in the state of health; it is by the abnormal manifestations of the same elements that diseases are characterized."

Best known of Bernard's physiological principles is that of the maintenance of the internal environment, and he himself was frank to say that he was the first physiologist to state clearly this concept.[5] But it is not alone the constancy of this internal environment that interests him. It is equally the reactivity of the internal environment with the external. "The organism," he wrote, "is only a living machine constructed in such fashion that, on the one hand, there is free communication between the external environment and the organic milieu interieur, and on the other, that there are protective functions of organic elements holding living materials in reserve and maintaining without interruption humidity, heat, and other conditions indispensable to vital activity. Sickness and death are only a dislocation or perturbation of that mechanism."

Of the many students and commentators of the work of Claude Bernard, probably the most influential in the English speaking world have been: Lawrence J. Henderson, in his two notable essays, *The Fitness of the Environment*[6] and *Blood: a Study in General Physiology*;[7] Joseph Barcroft in *The Architecture of Physiologic Function*;[8] and Walter Cannon in *The Wisdom of the Body*.[5] J. S. Haldane should also be mentioned in this group.

Henderson, whose primary interests were those of a biochemist and general physiologist, turned his attention first to the relation between external and internal environment as it concerned the "fitness" of such components as water, carbon dioxide, oxygen, and the compounds of carbon, both to constitute and to support organic life.

The next development, in which both the British and American physiologists of the early years of this century shared, concerned itself more with the milieu interieur itself. "It is the fixity of the milieu interieur which is the condition of free and independent life," was Bernard's now familiar statement, "and all the vital mechanisms, however varied they may be, have only one object, that of preserving constant the conditions of life in the internal environment."

Be it noted that all these men were physiologists, their interests directed chiefly toward normal bodily processes rather than disease.

A perusal of almost any of Barcroft's books will reveal that one could not find anywhere a physiologist with a more lively or wider range of interests. And yet he, too, had all the physiologist's preoccupation with the maintenance of normal performance. In the course of his many activities, he did join in some studies of disease states, but only as measurements of single episodes and not as persisting pathological conditions.

Walter Cannon, also, was a general physiologist in the best sense of the term. Let us look for a moment now at *The Wisdom of the Body*, the textbook, so to speak, of homeostasis, the book in which Cannon brought together his general thoughts about physiology and natural philosophy. We find here various fascinating descriptions of processes and sequences by which the body maintains its equilibrium, in respect to water, salts, sugar, temperature, blood pressure, and the rest, as well as an account of the large reserves which the body has at its command.

A number of acute and potentially lethal conditions are mentioned, such as shock, diphtheria, and heat stroke. But the emphasis upon acute diseases in which homeostasis fails is very light indeed. More important than this, there is no mention of chronic disease at all, except old age; no consideration of any of those slow, progressing, wasting, strangling forces by which most men die. It is with Cannon as with most physiologists of his day: not so much that they discarded chronic disease; as that they actually did not appear to be aware of its significance in the scheme of things.

The tone of Cannon's book is very reassuring. The Wisdom of the Body is such that "life, liberty, and the pursuit of happiness" should always be attainable, and Saint George dispose of his various dragons with agility and ease. Cannon himself is impressed with his own optimism. At one point about the middle of the book he asks a very ingenuous question. "If," he says, "the body can largely take care of itself, what is the use of a physician?" It may be a good question at that; but we cannot stop to answer it just now.

The influence of this book by Walter Cannon upon current medical thought, and medical writing, has obviously been immense. Physiologists, clinical physiologists, even the rising young clinicians must now call practically any bodily reaction homeostatic, since it always can be argued that the reaction is protecting something, or bringing some aspect of bodily structure or performance nearer a so-called normal. And all mechanisms have to be called homeostatic mechanisms.

Now the concept of homeostasis has great validity and great usefulness. No one should deny that, and I do not mean to. There are many and highly important mechanisms which are properly described as homeostatic. But is this concept of large enough scope to include the whole range of bodily performance, pathological as well as physiological?

As old-time clinicians perhaps we can take another look at certain disease processes, especially those of chronic disease, and ask ourselves once more about this never-failing Wisdom of the Body. One can start almost anywhere. Take the process of fibrosis, scar tissue formation. This heals wounds, disposes of infections—surely a homeostatic mechanism. But is it always so? What about scar tissue in rheumatoid arthritis, ending in frozen immobile joints, scar tissue in the kidneys, ending in glomerular nephritis, scar tissue in the liver, ending in cirrhosis, scar tissue in the lungs, choking the breathing process into asphyxia? In trying to be homeostatic in one direction, the body finds that it has been most un-homeostatic in another. It is like Macbeth's "vaulting ambition, which o'erleaps itself and falls on the other."

Or, take the many aspects of the hyperimmune reaction. Inflammation, ordinarily so helpful in mobilizing the body's defensive forces, has suddenly gone off the deep end in one or another odd and explosive fashion, with febrile, vasomotor, or tissue disturbances far out of proportion to the apparent stimulus or injury.

Or, take the growth response. Growth is certainly a necessary and vital thing. But when growth erupts beyond its rightful bounds, what then? What happens to homeostasis in cancer?

What, in fact, has happened to the Wisdom of the Body in all these phenomena? Is the body, indeed, so wise? No, one must conclude that it is not. It is stupid, egregiously, calamitously stupid. It seems, alas, that the body may be no wiser in the end than we ourselves, being itself, in fact, ourselves.

Someone might well write a companion book called The Stupidity of the Body. As author one could recommend almost any good, experienced, old-fashioned pathologist.

Georges Ungar, writing recently on the subject of inflammation and its control,[9] finds himself confused. "The introduction," he writes, "of the question of purpose into the pattern of inflammation, instead of helping to solve it, tends to confuse the issue. Inflammation is useful when it fulfills what, from a strictly pragmatic point of view, can be

called its purpose: fixation of the aggressive agent, and consequently, protection of the rest of the organism. Quite as often, however, inflammation serves no detectable purpose and can even be harmful. Neither of the two mechanisms can therefore be called unreservedly good or bad." I would say that this writer is confused, not by the events that he describes but by his own terminology. One need not bring purpose into the picture, but only recognize that a given process moves sometimes, if it is well controlled, to the net benefit of the organism, and at other times, with improper control, to the net harm.

At all events, it is obvious that so-called homeostatic mechanisms can go dreadfully wrong and end up by being most un-homeostatic. While this does not appear to be well comprehended by most physiologists, at least those of Cannon's day, it certainly was no secret to Claude Bernard. He was a pathologist as well as a physiologist, and thought very clearly in this matter. May I give his words once more? "It is by the normal activity of organic elements that life manifests itself in the state of health; it is by the abnormal manifestations of the same elements that diseases are characterized."

There it is, as simple as that. This is the other half of Claude Bernard's idea that Barcroft, Cannon, and most physiologists of the normal, have missed.*

You will have appreciated that Bernard has made a large generalization. If I understand him correctly, his position is that all pathological bodily processes are only modifications of normal processes. It would require knowledge of cellular activities and biochemical reactions far beyond anything that I have, to determine whether infections, atrophy, the cancerous change and such, should properly be considered as modifications of normal mechanisms or as new events, not seen in the normal. It may resolve itself into a question of assumptions and definitions. In any case it is beyond the scope of this argument.

What I wish to consider now is only that part of pathology that is brought about by so-called homeostatic responses leading, by reason of their excess, to bodily injury or death. This excess response accounts for a considerable proportion of pathological states. There are, of course, other mechanisms in pathology that are of equal or perhaps greater importance: atrophy, necrosis, and so forth. There are, probably, opportunities for more general classification here, but with these we are not now concerned.

* But some now are discerning the limitations of homeostasis (Hamilton,[10] Oliver[11]).

It will be obvious, upon reflection, that there is no fixed line between the homeostatic and the excess response. In many situations, a given process may be exerting both effects at the same time. In the intense vasoconstriction of traumatic shock, for example, there is both the homeostatic mechanism, tending to sustain blood pressure, and the excess mechanism, un-homeostatic, depriving organs, such as the kidney, of vital blood flow, with perhaps eventually total breakdown as lower nephron nephrosis. The process of fibrosis has been mentioned; this also may be at the same time homeostatic, and un-homeostatic in the direction of excess response. Another is hypervolemia in heart failure, the congestive state, apparently useful up to a point in filling a weakened heart chamber, but leading ultimately to total failure by way of excessive intravascular pressures and overdilated heart chambers. Many other examples will suggest themselves.

If, then, it is true that in many states, especially those of chronic disease, where the body is no longer wise, an important mechanism is the excess response, the question arises whether this is not an entity that should be identified by a name.

Hyperexis

"As a body which has one leg too long, or some other excess out of proportion, is an undesirable thing . . . and is the cause of a multitude of misfortunes to itself."—PLATO, *Timaeus*.

The *Timaeus*, the dialogue that follows immediately upon that of the Republic, has as its theme an even broader subject: the origin and nature of the created universe, and the place and functioning of man within this framework. The limited mathematics and physics, and exceedingly limited physiology of Plato's time, make much of the speculative reasoning in the *Timaeus* rather absurd to our view; yet within it are flashes of brilliant insight; and, as Whitehead has shown,[12] the basic questions and assumptions upon which it rests are still among the foundations of modern philosophic thought.

The quotation above is taken from a part of the dialogue's discourse on the familiar Platonic theme of symmetry and proportion; but its main purpose for us is that it contains the word excess, in this instance the Greek word "hyperexis." The derivation of this word is simple, and means "having too much." This fits our need quite well.

As compared with homeostasis, hyperexis as a word is somewhat inflexible. It does not lend itself to adjective-formation too well, and the antonym—hypo-exis, or an-exis—would be quite awkward. For a more manageable word, one might try hyper-

telesis, "beyond the mark," or "beyond the goal."

But do we want a word with an easy transition to the opposite and the negative of itself? Just because a physiological or pathological word can be expressed as an opposite does it mean that the exact opposite also exists in physiology and pathology? Take even the most common, atrophy and hypertrophy. We think of them casually as biological opposites. They are not. Hypertrophy is one thing—a number of different things, actually; atrophy represents another set of things, at the other end of the line, so to speak, from hypertrophy, but not in any biological sense an exact opposite. Our easy application of names sometimes obscures rather than clarifies what we are thinking about.

I am inclined, then, to vote for hyperexis, with the notion that, if it is worth anything, it ought to stand by itself.

Homeostasis and Hyperexis

In the endeavor to establish the validity of unhomeostatic mechanisms, in the above argument, it may appear that homeostasis itself has been slighted. There is no such intention. The two categories must exist, and do exist, together. The one represents a tendency toward unity, a dynamic uniformity and stability; the other an equally inevitable diversity, upheaval and "perturbation," uncontrollable change. In the dimension of time, homeostasis and the Wisdom of the Body hold for certain periods, greater or less, each a small cycle of the biological system under consideration; eventually to be displaced, or destroyed, as some larger cycle takes over, through, let us say, some form of hyperexis; or some more violent pathological process; or by way of slow decay: the "free and independent life" giving way to shrunken activity, invalidism, and ultimate dissolution.

Saint George and the Dragon

Finally, since Walter Cannon ventured to suggest the extension of the general notion of homeostasis beyond the realm of physiology into the world at large, there is good precedent for doing the same with homeostasis and hyperexis considered together.

It was Cannon's proposition, as we have already seen, that the homeostasis of the mammalian body might serve as a prototype for society—a system of checks and balances which should provide stability in an uneasy world: a series of Saint Georges to kill off the dragons of unwelcome change.

In the final chapter or "epilogue" of his book, Cannon compares physiological homeostasis with that which may be said to exist in the social, industrial, and political relationships of mankind, and points out many analogies. A hopeful picture is drawn of the possibilities for a better, healthier, more stable, more unified, less angry world. Yet with all the author's kindly optimism, one feels that some important things have been left out of the picture which ought to be there. For one thing, even if the social system is stable and secure, human beings will continue to suffer ill disappointment, calamity, sickness and death, all degrees and combinations of unfortunate or tragic occurrences. There is no lasting security. We suggest that this is not pessimism, it is simple realism. Any inclusive philosophy must face the pathological just as steadily as the physiological. We cannot all be lucky all the time.

In the larger social and historical cycles also, there must be and inevitably will be larger disruptions and perturbations. It was the most conservative, best protected, and most traditional of poets laureate who reminded us of the old order changing, yielding place to new. What changes will take place cannot be predicted, only that they will take place. Homeostasis may mitigate these great and devastating events—whether of natural or human origin—but it will not basically remove or prevent all of them. And perhaps these larger changes may still be homeostatic in the view of some larger entity. Our point here is that they are not homeostatic for the smaller entity.

There is nothing new in this. All that we are doing, perhaps, is to reintroduce to the currently modern mind an essential dualism which, in the thinking of past ages, faced and met reality rather better, in some respects, than we do now. One could argue, in fact, that much that is wrong with us, in this particular day and generation, and in this particular land of ours, derives from the life—liberty—pursuit-of-happiness, homeostatic, generally polyanna attitude that we have, and were born and raised in; that we expect too much good and are too impatient of ill; that we need to have driven in upon us more of the notion that the essence of living is struggle and suffering; that we need a more vigorous and fearless acceptance of the pathological; that pathology is as necessary a part of life as physiology, and dying as necessary as living; that hell and its devils are as real, and as important, as the angels in heaven; that our good Saint George, for all his valor, does not kill all the dragons, and that he will find, as indeed all saints have found, that the powers of evil still crowd upon him, when his arm has become weary and his sword is still.

May I summarize my argument as follows:

1. Homeostasis and the Wisdom of the Body,

admirable concepts in their place, do not adequately describe all bodily processes, especially those of disease. In chronic disease, homeostasis does not prevail and the body is not wise.

2. In looking for a wider approach, can we safely rest upon the more complete version of Claude Bernard's concept, namely, that disease is only perturbed activity of essentially normal elements; or is this still not enough?

3. In any case, an important category in pathology is the excess response, a homeostatic effort that overreaches itself, to the detriment or even the death of the organism. The term hyperexis is suggested for this type of excess response; a term that appears in Plato's *Timaeus,* and means "having too much." Other general categories of pathology are doubtless equally important and could be defined.

4. Pathology should be considered as well as physiology in general descriptions of living processes.

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LYCOPODIUM, THE CLUB MOSS AND GROUND PINE

The delicate plants of the genus *Lycopodium* leave their native haunts in woods, thickets, and clearings, on mountainsides and over the barrens in order to make their appearance among us at Christmas time. They have no economic usefulness to man save this one, that, although flowerless, they appeal to us and delight us with their simple grace and beauty, like their fairly near relatives, the ferns. To the botanist, however, club moss and ground pine speak of wonderful things, of days when the earth, far toward its poles, was clothed in a weird jungle of giant trees with strange scale-like and feather-duster foliage that reared above the swamps—swamps in which splashed the monstrous flat-headed amphibians that preceded the reptiles upon earth. *Lepidodendron* and *Sigillaria,* the giant club-mosses of the Carboniferous, fell into the acid swamps and were preserved and gradually converted into pure coal. Trains filled with holiday travellers run, lights illuminating Christmas trees glow, and cold hands and feet are warmed by means of the forests of giant club mosses that grew 200 million years before any man thought of digging them up and burning them, or of placing their surviving descendants around a Christmas wreath. It is an appropriate gesture of recognition.

(The superb photo of *Lycopodium obscurum* on the cover was made by Professor A. M. Winchester, Chairman of the Department of Biology at Stetson University, whose hobby is the photography of nature.)

The National Bureau of Standards

NATE HASELTINE

A veteran newspaperman, Nate Haseltine has been reporting since 1931, except for approximately three years when he served as an artillery man during World War II. He began specializing in medical and scientific news about six years ago. In 1949 he was made science editor of the Washington Post, *and for the past two years has been listed among the top ten science writers of the nation. His 1950 series of articles, entitled "The Human Heart," has been reprinted in pamphlet form for public distribution by the National Heart Institute.*

SCIENTISTS working together through the years have made life safer, simpler, and more secure. In the United States, they came from fields of individual endeavor more than fifty years ago to pool their efforts in a new surrounding, the fledgling National Bureau of Standards. Today, all Americans have benefited from the scientific achievements that have come out of the limited facilities that Congress created in 1901. The congressional sponsorship, tendered hesitantly, changed to ever increasing support that has paid off in national and individual terms of safety, convenience, and security.

For safer air travel, Bureau scientists developed ILS (instrument landing system) and uncovered many causes of air wrecks. For undersea safety in war or peace, they contributed an underwater antenna for submarines. For land travel, they produced the magnetic fluid clutch, and even determined the safest color tones for traffic lights.

In making ordinary living more comfortable, they set standards for electric light bulbs, tested such things as the wear and tear on shoes, and developed specific-purpose materials such as false teeth bases that will not shrink, break, or dissolve in mouth secretions or in the fluids that one drinks.

For national security, Bureau scientists made, in cooperation with scientists of the Applied Physics Laboratory of The Johns Hopkins University, the first successful radio proximity fuze for use in explosive missiles. The fuze and its successor models have been acclaimed the second greatest scientific achievement of World War II (second only to the A-Bomb, whose development was also aided by Bureau scientists).

All these and more were certainly not specific in the minds of those who at the turn of the century began their demands for a federal standards bureau. From 1870 to 1901, the government had an office of weights and measures which was operated by the Treasury Department, but the office was extremely limited in the types of standards it governed. It had no official standards of measurement that could be applied to the developing sciences. It had no yardsticks with which to measure the candlepower of light bulbs, no scientific bases for the accuracy of thermometers or barometers. Americans were sending their instruments to Germany or other European scientific centers for laboratory checkings and for the calibrations unavailable to them here.

The National Academy of Sciences took cognizance of the situation in 1900 with a resolution endorsing the movement for "a national bureau for the standardization of scientific apparatus." Prefacing this endorsement were the words: "The facilities at the disposal of the Government and of the scientific men of the country for the standardization of apparatus used in scientific research and in the arts are now either absent or entirely inadequate, so that it becomes necessary in most instances to send such apparatus abroad for comparison."

When the resolution was passed, the government was spending less than $11,000 a year to guarantee the uniformity of grocery scales, foot rules, flour barrels, and surveyor's chains; the Navy was sending its scientific instruments to Europe for calibration. The United States was ready for the benefits of mass production, but it lacked one of the basic requisites, standards of precise measurement for tooling to mass production.

The congressmen of the day recognized the high caliber of the scientists who were backing the move

Aerial view of the National Bureau of Standards laboratories, Washington, D. C.

for a new federal bureau but, although impressed, were reluctant to further a movement that, to them, looked like unwanted government control over commerce and industry. In addition, the new bureau would require money. A Tennessee representative protested on the floor of Congress that the sponsoring bill would set up "an enormous institution . . . it carries an expense of at least $250,000." Today, fifty-two years later, "the enormous institution" of that congressman's concept has grown to one with an annual budget of $6,000,000 for its own operation and together with fund transferals from other federal bodies, largely for defense projects, its working budget for the last fiscal year exceeded $50,000,000. Recently, the Defense Department announced its intention to relieve the bureau of administering major ordnance research and development programs, but the projects are to be continued in bureau facilities and with bureau personnel.

The National Bureau of Standards was created by a bill passed on March 2, 1901. Nine days later, Samuel W. Stratton, who was to serve for twenty-one years, was named its first director. Twenty-seven thousand dollars were allotted for the payroll of the Bureau for the first year. Although sponsors of the National Bureau of Standards had requested that its director have an annual salary of $6000, Congress reduced this to $5000, perhaps because congressmen were being paid the lower salary.

For $25,000 eight acres of rolling farmlands, in what was then cow pastures of northwest Washington, were purchased, and there two laboratory buildings—still in use—were built. Today the Bureau, one of the world's best-known scientific institutions, consists of some seventy buildings, about twenty of which are major ones, set within a sixty-eight-acre park surrounded by apartment buildings, stores, and private homes. Sixty additional

acres were acquired slowly at great cost to meet an ever present need to expand. The original staff of eight in the small old Office of Weights and Measures has grown to the present Bureau staff of about forty-six hundred.

The Bureau is no longer physically confined to Washington. It operated, until its recent shift to the Navy, a missile development installation at Corona, California. It operates special cryogenic engineering and is building new radio propagation facilities at Boulder, Colorado. It operates numerous small field stations for such things as ionospheric observations, cement testing, and radio time and frequency service.

Even at its present state of expansion, the Bureau is still a laboratory of individual research scientists. Here is scientific freedom for the study of the constants of nature, the physical properties of basic materials, and the fundamental standards of measurement. Here scientists work together, their successes speeded by their cooperative efforts and by the corps of technicians, skilled craftsmen, and administrators gathered together for scientific advancement. Here individual genius is inspired to greater accomplishments than might have come from solitary research.

In the Bureau's laboratories an atomic clock was fashioned, an infallible timepiece calibrated to vibrating atoms instead of to swaying pendulums. This new clock's potential maximum of error is less than the loss or gain of one second in a span of three hundred years. An atomic standard of length has also been developed in the form of a lump of mercury-198, an isotope obtained by bombarding gold with neutrons. Atomic standards of weight, or mass, are also being considered by the scientists working at the Bureau.

In 1901, the Bureau inherited only two standards, the meter and the kilogram. Now it has set more than forty different kinds of scientific standards, and these standards for commerce, industry, and science total more than seven hundred, some five hundred of them in chemicals alone. It has the standard for the length of an inch, the weight of a pound; standards for the range of temperatures from the coldest 459.6 degrees below zero Fahrenheit to 6000 degrees of rock-melting heat. Without its standards for electric power, radio wavelengths, and atomic radiations, American technology would long have remained stifled. American industries today send their gages to the National Bureau of Standards for periodic calibrations. And where industry may require an accuracy of measurement to within one part in one hundred thousand, the Bureau's instruments will check to a degree of one part in one million. By increasing its accuracies over the years, the Bureau has helped make mass production as it exists today. Now, tiny machine parts made in one city will exactly fit other instrument parts made elsewhere, for final assembly in still other locations.

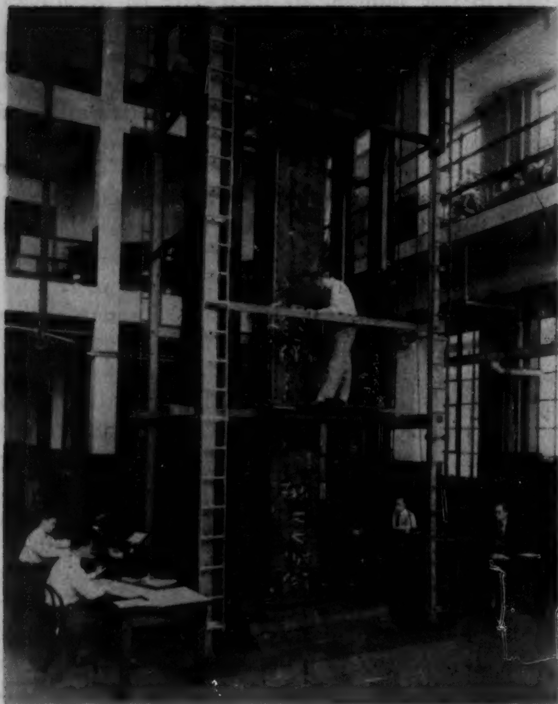
The setting of measurement standards was the primary reason for founding the Bureau, but the standardization work branched to fields undreamed of when the Bureau was started. Government agencies and industries soon began to ask more and more from the National Bureau of Standards. The United States then, as now, was the biggest purchaser in the country and, like any good buyer, wanted its purchases to measure up to the rights of the buyer. The Bureau was called on to test the materials, particularly cement for dam-building projects, for which the government was to pay. Manufacturers first used the services of the Bureau for checking the accuracies of their scientific instruments, but it was not long before other producers also turned to the Bureau for help. In 1907, for example, at the request of the American Foundrymen's Association and the Association of American Steel Manufacturers, it undertook the analysis and distribution of standard samples of steels and irons which industries needed for their own comparative checkings. Later, it cooperated with the American Chemical Society to ensure uniformity in technical analysis for the improved quality of chemical reagents.

These jobs taken on by the Bureau and the almost Herculean tasks it assumed during the wars are not specifically designated in the law which created the National Bureau of Standards. The bill that President McKinley signed in 1901 described the Bureau's *raison d'etre* in these words:

> Sec. 2. That the functions of the bureau shall consist in the custody of standards; the comparison of the standards used in scientific investigations, engineering, manufacturing, commerce, and educational institutions with the standards adopted or recognized by the Government; the construction, when necessary, of standards, their multiples and subdivisions; the testing and calibration of standard measuring apparatus; *the solution of problems which arise in connection with standards*;* the determination of physical constants and the properties of materials, when such data are of great importance to scientific or manufacturing interests and are not to be obtained of sufficient accuracy elsewhere.

The all-inclusive "solution of problems" clause became the authority wherever there was doubt that the Bureau could legally take on a research project for other government agencies, or for industry, or private groups such as the baseball leagues.

* The italics are those of the writer.



Experimental arrangement at the Bureau for studying the effects of perforations on the strength of a steel such as used in the Calcasien River at Lake Charles, Louisiana. A ten-million-pound testing machine has provided engineering data on full-scale structural units ranging from steel girders and aircraft components to structural building elements. Accurate calibration of the largest testing machines is possible since the development of four strain-gage dynamometers capable of measuring forces up to six thousand tons.

The Bureau undertook one baseball study to solve the annual complaint that home-runs records were being broken because baseball makers were producing livelier balls. By rigging up a baseball batting device, Bureau scientists found that the complaint was not justified. The balls, old and new, showed the same liveliness.

Much of the work of the Bureau has been done to make the work of others easier. Take the dollar bills you use today. They may not go as far as the dollars of years ago, but they get there in better condition. The paper currency of today seldom tears because Bureau scientists test the paper stock on machines that fold and unfold it thousands of times. If the paper is not strong, it is not used to make money. Bureau scientists, also, invented an electronic machine for the more effortless counting of mutilated and outworn paper money that is to be destroyed.

Occasionally, the Bureau employees are used for some of its testings. Not content to rely upon the results of machine-testing of shoe soles, the scientists outfitted Bureau guards with shoe soles of the material under test and let the guards wear them out normally; when its scientists were testing the new plastics now widely used in dental fillings, the Bureau called for volunteers—employees willing to have their cavities filled—for science and for free.

Some of the major contributions of the National Bureau of Standards to science and technology, not already mentioned, include:

1904 Development of the first luminous (Neon) tube. Luminous script signs in glass tubes containing noble gas excited by electric discharges were first made by Bureau scientists and exhibited at the Louisiana Purchase Exposition in St. Louis, Missouri. It was twenty-six years before the development was commercialized and a new advertising medium was established.

1905 Invention of the deflection potentiometer.

1907 The making of the first optical prism of silver chloride. Since the discovery that rock salt was transparent to infrared energy, a search has gone on for other materials having similar properties. The original silver chloride prism turned black after exposure to light, but recently a successful technique has been developed for polishing that material.

1910 First complete international uniformity of electric units. The Bureau served as host to the International Technical Committee on Electrical Units and for the first time established complete international uniformity in this electric field.

1912 The first comprehensive study of methods of measuring heating values of gases.

1914 Establishment of standards of radiant flux. The standards, used principally for calibrating thermopiles, were first issued by the Bureau in the form of calibrated carbon-filament lamps. The standards have been furnished to national laboratories throughout the world as a uniform basis of radiant energy measurement.

1915 Radio direction finder. Invented by Kolster and Dunmore and improved over the years, it is now in general use by all commercial airlines.

1917 The development of a method for slip-casting large refractory pots for use in melting 1000-pound batches of optical glass. Previously, optical glass was melted in hand-made pots of non-uniform quality, thus producing glass containing numerous flaws.

1918 Infrared detection. Bureau scientists pioneered in the detection of distant objects and signaling by infrared rays. This work contributed significantly to military research for both world wars.

1920 Development of the dental interferometer

for measuring the expansion of dental amalgam, a device for accurately measuring the setting expansion of dental filling materials.

1922 Development of a precision high-speed oscillograph camera.

1922 Invention of the first alternating-current radio set, perhaps the most revolutionary development in radio. This invention put radio in the home.

1925 Beginning of the standard frequency and time interval broadcasts.

1926 Development of a camera for photographing the interior of a rifle barrel.

1929 Engine ignition shielding in aircraft.

1929 Casting of the first large telescope reflector (70 inches) in the United States.

1931 The first x-ray protection code. The Bureau was the first organization to bring about general unification of x-ray and radium protection codes.

1935 A method for determining the fineness of portland cement.

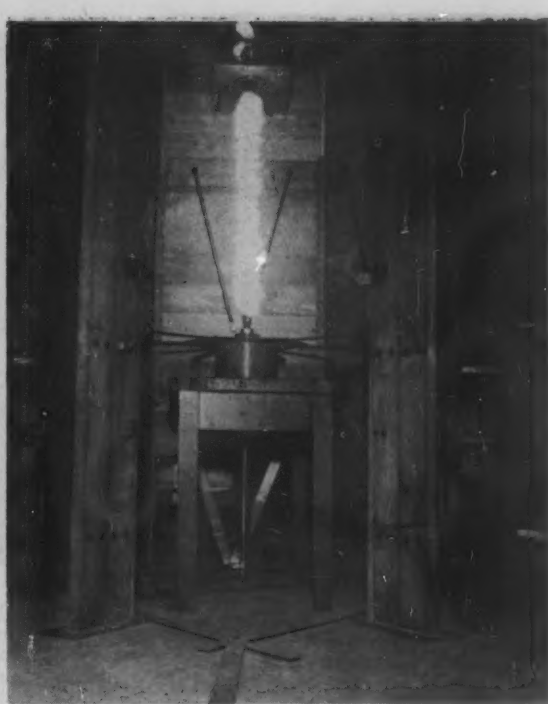
1936 Application of telephoto lenses to eclipse photography.

1936 Development of a radiosonde system, one of the most important contributions to the science of meteorology.

1938 Measurement of the gains of hearing aids for their users by a cavity pressure-testing method.

1940 Discovery of the cause of, and a remedy for, white-coat plaster failures. This was the first comprehensive study of the cause of such plaster failure, and the development of a treatment for limes that eliminates the possibility of expansion failures of plastered walls already in service.

A precision instrument for calibrating airplane mapping cameras, developed by the Bureau, is tested in the optical instruments laboratory. The test involves determining the angular deviation between collimators in the collimator bank beneath the table.



A 100,000-ampere current surge is measured during discharge by means of a special shunt (beneath table) developed in the Bureau's high-voltage laboratory. Improvements in the design of electric power systems and their component parts have greatly reduced power failures from lightning. These improvements are a result of the use of surge generators.

1941 Radio proximity fuze for bombs. As mentioned previously, Bureau scientists developed the first proximity fuze for use in nonrotating missiles such as bombs and mortar shells. Meanwhile, scientists at The Johns Hopkins Applied Physics Laboratories were developing radio-detonating fuzes for rotating missiles such as artillery shells. Radio proximity fuzes were credited by some with shortening the course of World War II.

Bureau scientists have not taken a group monopoly on research in the way that individual scientists, working alone, long held secret monopolies. Instead, as in the instance of the proximity fuze research, the scientists of the Bureau solicited the help of the entire electronics industry and shared their findings within the limits of military security.

In 1941, too, scientists under the direction of Dr. Allen V. Astin, who later succeeded Dr. Edward U. Condon as Bureau director, pioneered the research in telemetering from missiles in flight. If there are any passenger space ships of the future, space travelers can credit the National Bureau of Standards for much of the research that made their transportation possible. At the present time

The Bureau's standard x-ray ionization chamber for use in the 500,000-volt range. Several primary standard ionization chambers that permit the calibration of devices over a wide range of x-ray energies are maintained.

this telemetering is a major tool in the development of guided missiles and other electronic ordnance devices.

Many of the research and development accomplishments of World War II are still muffled by security regulations, but during the war years, Bureau scientists developed a test for weather resistance of porcelain enamels, a way to extract alumina from clays and high-silica bauxites, a T-bend test of the welding qualities of steels, and a way to coat metals with ceramics resistant to high temperatures. They also advanced the development of special-purpose batteries; found out why certain dental fillings backfired on the patients, and produced extreme pain; developed a wind speed and direction indicator used principally at airports in aircraft takeoff tests; and in 1944 produced the first successful guided missile, "The Bat."

Bureau developments and research pushed to successful stages after the end of World War II included studies on the use of concrete as a high-energy radiation shield; printed circuit techniques, for miniaturizing electronic gear; and a spectroscopic lamp containing artificial mercury-198, improving the accuracy and convenience of precise length measurements.

The Bureau's list of accomplishments over the years is seemingly endless, and many that may be of tremendous importance in future developments are not included in this abbreviated listing.

The National Bureau of Standards is a government agency, without independent federal status. It is only one of the divisions of the Department of Commerce. Unfortunately, the nonscientific public has come to regard the Bureau, erroneously, as a testing laboratory for marketed products. The recent furore over a controversial battery additive, AD-X2, aided and abetted this public concept. Once again the Bureau was flooded with requests from consumers, most of them seeking advice regarding the purchase of automobile batteries. The reaction was a discouraging one to the scientists and their fellow workers, who would like the public to know that the primary function of the Bureau is not that of a consumers' research.

When the Secretary of Commerce, Sinclair Weeks, tried to dismiss Dr. Astin as Bureau director, he raised a storm of protests from scientists throughout the United States. Mr. Weeks charged that Dr. Astin was not sufficiently objective, and lacked the business point of view, because Bureau scientists found no value in a commercial battery "dope" which, its maker claims, will lengthen storage battery life. Bureau scientists welcomed the support of their colleagues, but they were irritated by the public's reaction in besieging them for advice as to which products—be they floor wax, soap, or auto batteries—are the best on the market.

To set the nonscientific public straight, only one per cent of the Bureau's work is concerned with product testing, and such testing is for other government agencies. Only one-twentieth of this one per cent deals with "market-place" products, such as the mixture for rejuvenating auto batteries. The other nineteen twentieths concern tests of materials purchased by other government agencies, such as cement for dam-building, lights for government buildings, and tires for government cars.

Because the Bureau is a federal operation, its scientists are justifiably worried whenever the national administration changes hands. Fears and worries hang heavily now, as they did when President Franklin D. Roosevelt swept the Democrats into power in 1932. With that change, about one-third of the Bureau's personnel lost their jobs; many, however, regained them within a year.

The agreement between Secretary of Commerce, Sinclair Weeks, and Secretary of Defense, Charles E. Wilson, to separate the Defense Department's major ordnance research and development programs from Bureau administration (although the contracts were to be continued at Bureau facilities and with Bureau personnel) only increased fears of political "high jinks." Some $35,000,000 of transferred funds in the Bureau's current fiscal program, and some eighteen hundred of its forty-six hundred employees, were involved. Some described

the move as only a paper transfer; others thought it was a beginning of an eventual dispersion of the Bureau's advanced research and development projects to private industry.

When Secretary Weeks first proposed releasing Dr. Astin, it was not the first time that a director of the National Bureau of Standards faced a job-severance. Actually, however, the Bureau has been relatively free of political interference—save, perhaps, somewhat periodic surveillance by congressional committees and the harassment of individual members of Congress who seek favors and services for themselves or their constituents. Dr. Astin took office as the fifth director of the National Bureau of Standards June 12, 1952. The four directors who served the forty-nine years before him did so under nine presidents and eighteen secretaries.

The first director of the Bureau was Dr. Samuel W. Stratton. He took office March 11, 1901, and resigned December 31, 1922, to become president of Massachusetts Institute of Technology. Appointed by Republican President William McKinley, he served under the succeeding Republican administrations of Theodore Roosevelt and William Howard Taft, and the Democratic administration of Woodrow Wilson. He resigned under the Republican administration of Warren G. Harding as the result of differences with Herbert Hoover, then Secretary of Commerce.

George Kimball Burgess became the second Bureau director April 21, 1923, following a brief period during which F. C. Brown served as acting director. Dr. Burgess died in office, July 2, 1932, after serving under three Republican presidents, Warren G. Harding, Calvin Coolidge, and Herbert Hoover.

Lyman James Briggs took office as the third director June 13, 1933, and retired at the age of seventy-one November 5, 1945. Dr. Briggs, an assistant director when Burgess died, immediately became acting director and served in this capacity until his official appointment as director by President Franklin D. Roosevelt. President Herbert Hoover had sent to the Senate Dr. Briggs's name as Bureau director. The Senate, however, took no action on it, presumably in view of the defeat of Hoover and the Republican party in the November, 1932, elections. President Roosevelt sent Dr.

Standard weights used by the Bureau for calibration of standards for modern micro-balances (values range from one gram to 0.05 milligram). Methods have been developed for calibrating standard weights below one hundred milligrams with a precision of one or two ten-millionths of a gram.

Briggs's name to the Senate again in April, 1933, and the appointment was confirmed. It was reported in the press of the period that, in regard to Dr. Briggs's appointment, a reporter asked the President, "What are his politics?" To which the President replied, "I don't know; I never asked him. Everyone says that he's the best man for the job." Dr. Briggs served under Presidents Roosevelt and Truman, and under four Secretaries of Commerce. He was permitted to serve beyond normal retirement age of seventy at President Truman's request, when the country was still at war.

Dr. Edward Uhler Condon, now president of the American Association for the Advancement of Science, became the fourth director of the National Bureau of Standards November 6, 1945. He served until the effective date of his resignation, September 30, 1951, when he became director of research and development at the Corning Glass Works. Dr. Condon was appointed by President Truman, and served under three Secretaries of Commerce, Henry A. Wallace, W. Averell Harriman, and Charles Sawyer.

Problems and Parameters of Science Literature*

HAROLD OATFIELD

The author was educated at Reed College, Rice Institute, and Iowa State College, where he received his M.S. (1933) in organic chemistry under Professor Henry Gilman. After working in a control laboratory of Crown Zellerbach Co., he spent 11 years as a member of the Intelligence Division, DuPont Experimental Station. From 1945 to 1947 he participated as a Library Research Fellow in an experimental program at Massachusetts Institute of Technology. He was a professional associate in the Division of Medical Sciences, National Research Council (1947–1951), and served as secretary for the Committee on the Future of the Army Medical Library. Since 1951 he has been a literature research chemist with Chas. Pfizer & Co., Inc.

According to an editor of the *Manchester Guardian*, there are in fact no longer four philosophical elements but five: earth, air, fire, water, and *paper*. Even he thinks too much of the last element is used in sound, soporific gobbledygook.

A parameter, I need hardly remind you, in mathematics is a quantity constant in the case considered, but varying in different cases. I view the major parameters of science literature as: ethics, publication, distribution, understanding; and in an effort to clarify for myself what dizziness is involved therein, I have grouped under those headings selected problems for consideration. Many other permutations exist. Let me say at the outset, I have no key to the problem of breasting the tide of scientific publication—I merely suggest channeling it into fewer secondary outlets.

At least four of the six premises† of today's code of ethics for scientists apply to literature: the sharing of new knowledge, the obligation to publish important findings, the necessity for veracity, and the recognition of priority. What is the ethical code for the scientist in respect to the relation of his science and his discoveries to the community and to the race? We still argue without agreement. But it is clear that we should prepare an addendum to the code comparable to the Hippocratic oath of physicians.

Du Bridge[1] has stressed the "problem of converting our expert knowledge of scientific problems into intelligent proposals for political action to meet them,". and points out that in this sphere we are laymen though we may not care to admit it. Erskine[2] then steps in to advise scientists not to regard themselves as a caste able to think dogmatically for all. More thoughtfully, Bronowski[3] has described science as a giving, material and spiritual. He shows how its values rest in human fulfillment, in contrast to a standard of ascetic denial promulgated as the basic moral quality of the past and still so considered by many nonscientists today. Bronowski warns us to be alert to defend from misapplication both scientific method and the mind that employs it.

In humanism an earlier civilization gave us the concept of improving culture for ourselves and our descendants by (1) striving for truth or intellectual excellence and the ordering of knowledge—what we call science; (2) placing that knowledge with reference to the rest of life—or the development of wisdom; and (3) applying that wisdom in daily life—or prudence. Today we are neglecting to round out that concept by exercising prudence outside the laboratory.

Let us pass over the hoary problems of how to train the user of scientific information to seek it out for himself, and the unwieldiness in use of the existing bibliographic aids for arranging knowledge due to the volume of material, accrued and accruing, that must be winnowed. What I am concerned with seems to be an ebb in the tide of cooperation among scientists. You may voice thousands of examples to the contrary and mention every committee in the country. We all have taken a vicarious pride or better in the pooling of effort and achievement in a Manhattan project or the development of penicillin. It is not surprising that there is cooperation. It is the lack of it that seems to violate scientific ethics. The multiversity of specialization within the twentieth century has been built upon a

* Based on a paper presented at the 118th meeting of the AAAS, Philadelphia, Pa., December 30, 1951.

† The others: maintenance of integrity; striving for refinement of method.

base of continuing cooperation and interdependence. When one unit fails to do its part, it reflects broadly on the interests of the others. These are a few indications. It must not become a trend.

Some years ago a mathematician abroad sent a manuscript, an original contribution, to an august American institution. Because he was not a member of that institution, his paper could not be published in its journal. Meanwhile, the war cut off communication. Among scientists, no less than for the rest of circulating mankind, word of mouth conveyance of information abounds. During World War II scientist A of the aforesaid institution hinted to mathematician colleague B at another institution that this manuscript might have an important bearing on a problem which B was currently attempting to solve in connection with the war effort. A request was made for a copy of the manuscript. Due deliberation by the governing board (predominantly of scientists) of the institution concerned led to denial of the request. Further appeal proved fruitless until high officials intervened. To what avail custodianship without related use?

Again, an institution had in its files a unique copy of a map of certain waters. During the war that institution was requested to release the map for government use. This request did not meet outright refusal, but was handled by eventually turning the map over to a national repository. The war was nearly won by the time it emerged from "processing" to reach the requesting agency.

A great university's financial resources have dwindled owing to the character of the times and the draining off of potential students by the Korean campaign. It attempts to recoup in part a resulting cut in its library budget by charging for outside use of its library resources. That reversion to nineteenth century society library tactics may be a small price to the individual user for the convenience provided, but multiplied on all sides the practice would spell the end of the interlibrary loan policy, which in this century has aided scholarship and research of all sorts so markedly within the United States through sharing of technical resources.

A zoologist acquired by unorthodox exchange a book published behind the Iron Curtain, a book which contains descriptions of a half dozen new species not yet indexed elsewhere. Did he send a note of apprisal to the appropriate Record, or tell his acquaintance, scientist C, who had worked with organisms of this class for years? Certainly not! Has the stoic sense of civic duty gone out of practicing scientists? No, but science does not alter human nature. Nevertheless, being his brother's notekeeper should not relieve a scientist from responsibility to share knowledge.

There is no need to elaborate upon political restrictions placed on scientific thinking, on exchange of information, and on circulation of scientists themselves. The decline of scientific cooperation on the international level must not become an excuse for loss of the spirit of cooperation among scientists either as individuals or in groups. The next retrograde step would be failure to impart new knowledge via publication. The quantity of publication now pouring forth continually induces vehemence in scientists. How changed their tune of invective would be if a serious decline in publication volume were to occur! Under our present publication setup there will hardly be scientific publication at the expense of security. Even granting the premise of an unwary editor, material, except in notes and dribbles, could not be issued that fast.

A prime problem is what to do with new-found knowledge. When a man has convinced himself that he has found out something worth telling his associates, which he can impart without violating his principles, established policies, or patriotism, and when his compeers, the editor and referees of the journal of his choice, have agreed, Karma, or the inevitableness of the act, enters a little Carnot cycle stage. You will recall that Carnot's classic cycle involves an ideal heat engine, consisting of a conducting cylinder that is closed by a nonconducting piston and containing a quantity of a perfect gas. This working gas goes through four successive operations, alternatively in temperature baths and insulating jackets: (1) isothermal expansion to a desired point (the temperature remains constant but the gas volume increases); (2) adiabatic expansion to a desired point (work is done by using up a part of the intrinsic energy of the system without adding from an outside source); (3) isothermal compression (heat is given off) to such a point that (4) adiabatic compression brings it back to its initial state. In the publishing analogy the original data expressed in a paper represent the gas, and the heat engine components are editors, journals, and scientists: (1) primary publication passes isothermally to secondary publication in due time (no new knowledge is created, but we have more paper dealing with the same facts); (2) adiabatic expansion is paralleled by expansion of subject entries in indexes; (3) isothermal compression occurs as the searching scientist passes from volume to volume (he gives off heat); and (4) the published data come full cycle, as though by adiabatic compression, when they are used in a new publication

or cited in a review. Thus, the world of scientific publication conforms on this plane to the second law of thermodynamics.

There is publishing entropy, too. Entropy is the measure of the unavailable energy in a thermodynamic system. In the scientific publishing system, lost facts and unindexed papers comprise its entropy. Thermodynamically, we realize that the lack of perfect conductors and insulators makes reversibility unattainable in the Carnot cycle. In the analogous cycle of recording scientific findings we also have our imperfect conductors, the abstracts and indexes. I would hesitate to acclaim any scientific paper as an ideal gas. That bit of published knowledge may be applicable toward the solution of another man's problem. This man has not only the personal obligation to become aware of its existence but, once aware, to locate it physically so that he may examine it. Photostating and like means have solved the matter of retaining working copies.

In the problem of location, the man of science tends to fall back on a librarian for help. Libraries have carried out the organization of catalogs of scholarly resources, as well as mapping techniques related to their storage problems, in order to be able to locate material with minimum delay when requested. Librarians continue protesting that there is no coordination among existing abstracting and indexing services and that the resulting duplication runs up their operating costs unnecessarily. They try to render equal service subject-wise to their varied clientele, yet gaps in coverage continue. The multiplicity of record does insure each worthy client the particular assistance he requires. Through his professional society the scientist client must táke the initiative and responsibility for secondary publication and for the gradual improvement of its character. He must see that a service of that sort adequate to his group needs is produced, and that once established it is not allowed to languish or devolve into limited correlative usefulness. The fact that your fundamental science has already met this problem, or met it five times over, does not give you the privilege of ignoring it. Next month or next year another society to which you grudgingly pay dues may decide its particular literature interests are not now being well served. Is the bryologist unhappy with the *Index Kewensis?* Not that I have heard. Can the helminthologist make do with *Biological Abstracts?* Or the *Q.C.I.M.?* Where is Echo? Probably buried in the pages of *Helminthological Abstracts.* Does the phthisiologist need a *Tuberculosis Index,* the *Q.C.I.M.,* and the *Current List of Medical Literature,* as well as the abstracts of the *American Review of Tuberculosis, World Medicine,* or *Excerpta Medica* (to choose only within the English language)? Let us cooperate to reduce the number of these secondary publications and strengthen and expand those retained. Then we can riffle fewer pages with a saving in time to locate the same amount of information. If supplementary financial support is necessary to transfuse a weakened index, the scientist collectively may seek assistance from government and industry who also derive benefit from these tools. But the primary load must be borne by and the drive for having the abstracting or indexing service must come from the learned society itself or several such societies acting jointly. Is it too much to hope for further extension of cooperation between learned societies, as exemplified by the American Physical Society and the American Chemical Society who now agree on periodical abbreviations to be used in their publications? Or as between physicists in England and in the United States for one abstracting tool?

The difficulty of locating unpublished documents, those near-print publications which were spawned in such profusion by governmental research contracts during World War II, has been resolved by key government agencies, such as O.T.S., the Library of Congress, the Atomic Energy Commission, and the Department of Defense. These agencies have acknowledged their responsibility to reduce to order the main body of those cluttered contributions and their continuing postwar stream.

We hear occasionally about the gaps in the organized coverage of knowledge and uncertain figures on the annual amount of published work that does not find its way into the main current of secondary recording for the sake of future reference and potential application or extension. It should be the responsibility of those who raise the issue (and who obviously must feel this lack most keenly) to convey to the scientific public not only the importance of the missed knowledge, but some more adequate conception of what it comprises and how it can be suitably encompassed. Have we crusading critics armed with facts? A solution seems to be evolving in UNESCO for that material coming from workers in geographically isolated areas, through new regional publications for documenting serials. What of foreign patents? Are they being given adequate treatment?

It has been claimed that no communication has lasting value unless it influences and modifies human behavior, either of individuals or of masses. When it does that, it attains social significance. But in science who shall say when that influence will begin to be felt? Will each crucial new contri-

bution have a Meitner to herald at once its applicability, or will it lie dormant or buried like contributions of Gibbs or Mendel until times are more receptive or propitious, or until supporting knowledge has been advanced to a point to meet it halfway? Future generations may scorn or ignore much of what we prize today. If they are solely dependent on the author's original account, they may also have a trying time deciding what it was we had ascertained or what we meant to convey, let alone the merit and utility of our findings. In the time of Isaiah, it was a vexation to understand the report. In the time of the Skeptical Chymist, Boyle pleaded with his Fellows for a clearer style in writing and avoidance of unnecessary subtleties which do not increase knowledge but merely puzzle men. In the time of Andrade, which is today, a plea is still being entered that the scientific account be kept free from unnecessary clumsiness and obscurity. Authors of scientific articles need not disregard syntax to establish their credit. They may safely dust off the copybook virtues of sincerity, clarity, and simplicity in writing, and then resort if necessary to compression. They are again exhorted when so doing to attack one subject at a time and to remember that not all readers have the nimbleness of goats in leaping elliptically from topic to topic without transitional stepping stones. Obscurity in scientific writing has yet to be hailed as a virtue. Recently the Royal Society went so far as to invite authors to write for the hundreds who might be interested in some aspect of a well-written paper rather than for a specialist handful.

Scientific motion picture film literature resources are looming larger as basic records and as texts and are well entrenched as means for imparting techniques. The organization of film into the scientific record constitutes another literature problem. I will not risk further blurring of this outline by discussing film here, but merely call your attention to it.

The solution to some of the problems cited appears to lie in maintaining cooperation in the exchange of knowledge: cooperation between scientists as individuals, as groups in societies and institutions, and internationally; and between scientists and other organized contemporary groups. Let us seek expansion wherever cooperation actively exists today, as in the improvement of secondary literature resources by reducing the numbers of such services, but concomitantly by increasing the specific scopes of those retained, and work to revive cooperation where it is discovered to have lapsed. One of the peripatetic correspondents of the *Lancet* says that "Highly educated people only seem more reasonable." To advance, scientists must do more than "seem" cooperative.

Publications ripple the surface of the sea of knowledge, increasing by greater or lesser degree the solute content. Yet the body remains essentially in repose. Its level never drops but deepens, for knowledge does not evaporate from the record. Items may sink to unfathomed places, but knowledge departs only when the record itself is destroyed, or it fails initially to get entered in that record. Paul Schilder[4] in his monumental book, *Brain and Personality,* remarks, "It's strange that we know so little about the state of mind of a dizzy person." I submit that the scientist has been made professionally dizzy by having to cope continually with waves of that fifth alchemical element, paper. Prudent cooperation in its use, preparation, and dissemination would help to restore normal equilibration in the advancement of knowledge.

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The Teays River, Ancient Precursor of the East

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A mighty river, coursing toward the sea, presents a wondrous spectacle of power, strength, and endurance. Its surging waters have cut into the bedrock and stripped away the strata which once lay across its valley. Unceasingly at work, it has become the master of its environment, entrenching itself into the landscape of which it is a part. The stream is the creator of both the valley and the hills; and in creating them, the river inscribes the history of its own eventful past.

The pathway of the river, however, may sometimes be beset with difficulties. Upheavals of the lands, invasions by the sea, advances of glacial ice, landslides, all tend to turn the river from its course. If they be great, the river may be turned aside; if overwhelming, the river meets its end. Such was the fate of one of America's grandest rivers. Unseen by man, it was the master stream of a prehistoric age, a precursor of rivers that flow today.

More than half a century ago, geologists working in the basin of the great Ohio River first noticed certain peculiarities of the river valley. They saw that some portions of the valley seemed to be much younger than others, that some of the river's tributaries appeared to be older than the master stream, and furthermore, that certain confluent valleys showed evidence of former occupancy by torrential currents no longer flowing through them. This led to the conclusion that the Ohio River had not always flowed in its present course, but that during some time in its history it had abandoned portions of its well-established valley and had carved out another route. With this, it was reasoned, had come adjustments in its tributary drainage. Summarizing this accumulated knowledge and adding much of his own, W. G. Tight in 1903 worked out partial details of these changes.[1] Among these was the recognition of a great abandoned valley extending across West Virginia, from Huntington to Charleston, through which the Ohio River was presumed once to have flowed. Averaging a mile and a half to two miles wide and nearly fifty miles long, the valley is occupied today only by minor streams that drain the immediate territory and are incapable of having excavated so great a valley in the bedrock.

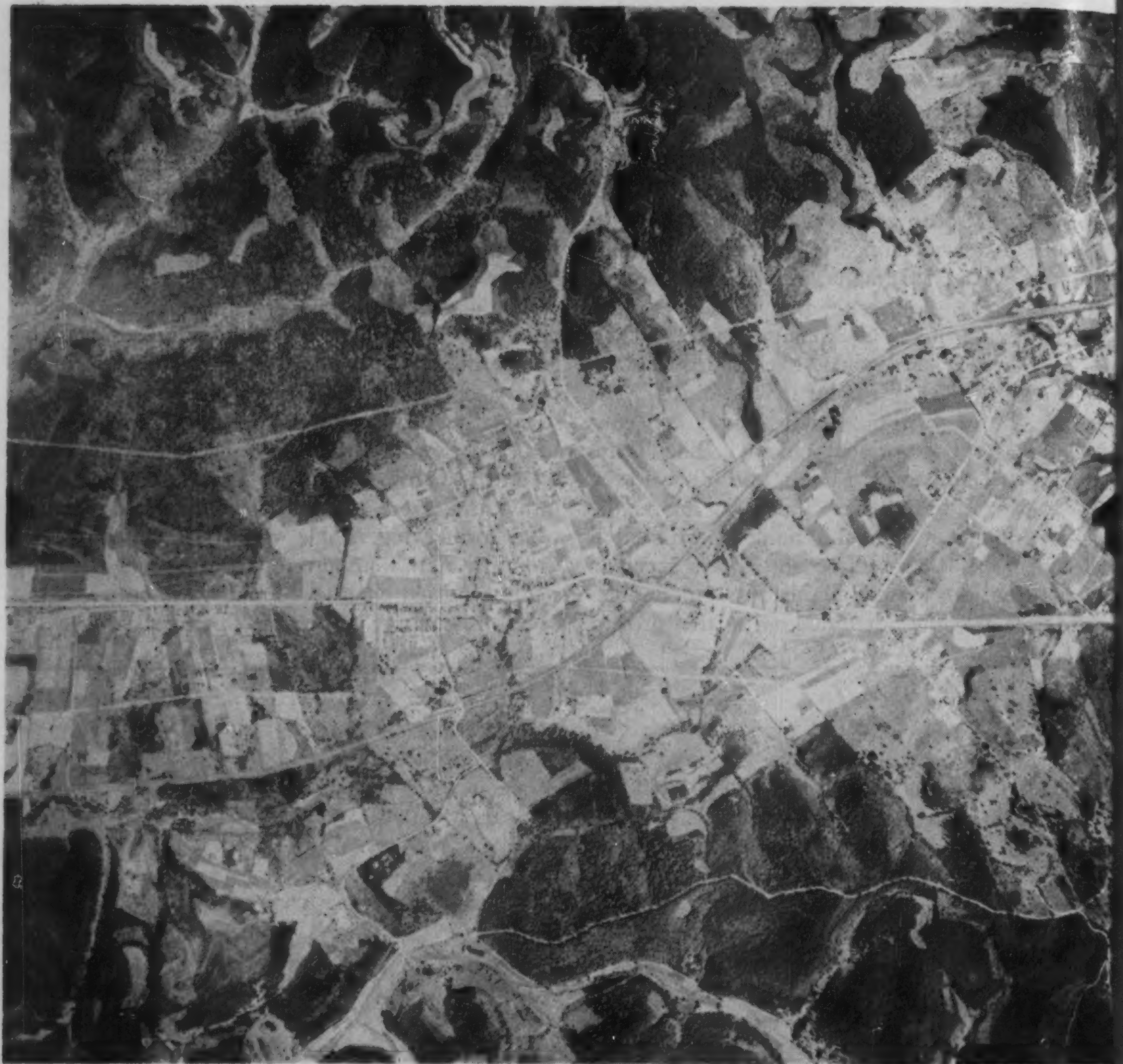
To this valley Tight gave the name Teays, from a tiny crossroads station located within it. He also applied this name to the former river which flowed through it to distinguish it from the present course of the Ohio River. He did not know that one day the name he had proposed would become applicable to a greater river—a river which was once the master stream of interior America, with the Mississippi as a tributary. He was unaware that the Ohio River had not yet been born when the Teays flowed across the lands. The story of how the Teays helped to carve a great continent, of how it ultimately ceased to exist, and of how the Mississippi later became the master stream of the interior was not fully realized until nearly half a century later.

The prehistoric Teays, precursor of the present Mississippi, and predecessor of the Ohio, the Illinois, the Wabash, and others, had its source in the Appalachian Mountains of North Carolina (Fig. 1). From there it followed a northwestward course across Virginia and into West Virginia as far as

Charleston, along the same route occupied by the New and Kanawha rivers today. From Charleston it continued due west through the abandoned valley to Huntington, and then swerved northward to Chillicothe, Ohio. Here it resumed a northwestward course past Springfield, Ohio, to the Indiana state line southeast of Fort Wayne. It then turned south and formed a great loop to the north. After reaching its northernmost point in Fulton County, Indiana, the Teays swerved southwestward to Lafayette, proceeded west into Illinois, passing near Champaign, swung down toward Decatur, and then back northwest to Lincoln, Illinois. At this point it was joined by its tributary, the Mississippi, which then flowed considerably east of its present channel. The Teays continued to Beardstown, Illinois, and followed the present lower Illinois River Valley as far as the latter's confluence with the modern Mississippi Valley near St. Louis. Here the Teays received drainage from the western plains through channels which later became identified with the present Missouri River. The Teays continued for a short distance past St. Louis where it emptied into the Gulf of Mexico, an embayment of which formerly extended northward to this point. Here was the mouth of the great Teays River. With its headwaters in the Appalachians in the East and in the Rockies in the West, the tributaries draining the Great Lakes region on the north and the Kentucky terrain on the south, the Teays was the master stream of a primeval America.

The discovery of this ancestral river was not the accomplishment of a single individual. It was the culmination of study and exploration made in recent years by a great many geologists working individually in the scattered territories through which the river flowed. Gradually it became evident that several streams, shown on present-day maps as individual rivers, are really disconnected portions of a former big, single river. Associated underground waters were also found to be moving along definite buried channels. Finally, the entire course of the ancient river became apparent.

FIG. 1. The Teays River and its chief tributaries in so far as they are known. Some of these still flow as surface streams today; others are completely buried under the glacial debris. Also shown are the northern extension of the Gulf of Mexico and the line of southernmost advance of the Ice Age glaciers. (Adapted from Tight, Fidlar, Ver Steeg, Lamb, and Horberg.)



The abandoned Teays Valley as seen from the air above the town of Culloden, West Virginia, about midway between Charleston and Huntington. The light portion through the middle marks the old river bed, and the forested hills rise on either side. The main line of the Chesapeake and Ohio Railroad and U. S. Highway 60 can be seen extending through the valley. (Courtesy of Chesapeake and Ohio Railroad.)

The Teays River had its origin many millions of years ago in the Ancestral Appalachian Mountains, a higher range of mountains, preceding in geologic time the present ranges. These earlier mountains were eroded to an almost level plain, and the Teays River was one of the rivers that had worn them low. Thereafter, it flowed westward across the great plain, which it had helped to create, toward an immense inland sea that covered the central part of North America. The river developed a winding, meandering course as it crossed the plain.

In the course of time, pressures from within the earth lifted the plain to a high plateau, with the uplift highest in the East so that its surface sloped westward toward the interior of the United States. At the same time, the great inland sea was drained away, except for a long narrow arm which extended northward from the Gulf of Mexico as far as southern Illinois. These changes did not destroy the Teays River, as it was carried upward on the surface of the rising land. With its gradient steepened, it continued to flow down the new slope to the sea at the northern end of the long arm of the Gulf. The uplift gave the stream renewed energy, and it cut its way downward through the uplifted rock layers. The course of the river could not be straightened; hence, it entrenched itself in the

drock, while retaining the shape of the mean-ring course which it had developed previously on e low, flat plain.

Evidence of this can still be seen in the gorge of e New River, which is the present name for the pper portion of the Teays where it flows from orth Carolina to central West Virginia. The ep canyon, with its nearly vertical walls and nding course, marks the extent of the river's osion since the uplift. Similar relationships may seen throughout the vast Appalachian region erever other streams have incised their valleys o the great plateau. From some high vantage int, such as those along the Blue Ridge Park-y, one can see that the Appalachian ranges of day are essentially flat topped and of nearly ual elevation in their highest parts. If one im-ines all the valleys refilled with the great quan-ies of rock that once were there, he has recon-ucted the vast, rolling plateau surface that isted before the valleys were cut into it. The esent Appalachian ranges, with their long, flat-pped summits, are remnants of the former pla-u which has been dissected by the stream-cut lleys between them. The Blue Ridge marks the stern limit and highest part of the former pla-u. The steeply tilted rock layers seen in the es of many of the ranges are the spreading ts of the Ancestral Appalachians, now re-ele-ted and dissected into numerous parallel ranges. nce, the Teays, older than the present moun-ns themselves, actually held its course while the drocks were pushed upward from beneath it.

The headwaters of the Teays consisted of at st two main forks. One, rising in eastern West rginia, is known today as the Gauley River. The her, rising in North Carolina, is the present New ver. It is longer, and was the main headwater annel of the Teays. It rises today near the resort vn of Blowing Rock, at the summit of the Ap-lachian Divide. Originally it extended much rther east to the present Fall Line along the stern base of the mountains. This was before the stern portion of the Blue Ridge was eroded to come the Piedmont area. Streams flowing down e east side of the Blue Ridge directly into the lantic had much steeper gradients than did the ays and others draining toward the Gulf of exico. Consequently, during the intervening s, the divide has been shifted farther and far-r west by erosion, resulting in the disappearance the uppermost headwaters of the Teays. Con-ry to its name, the New River, as the remaining adwater portion of the ancient Teays, is one of e oldest rivers in America. Because it was there long before the mountains were carved, it is the only river crossing the entire Appalachian belt from one side to the other.

The union of the New and Gauley Rivers at Gauley Bridge, West Virginia, forms the present Kanawha River, which was a part of the ancient Teays as far as Charleston, West Virginia. The valley of the Kanawha here crosses the heart of the vast Appalachian coal field. Along the steep valley sides can be seen the entries to coal mines which extend back under the hills on either side. Along the river banks are great chemical plants which process the many products made from coal.

A few miles below Charleston, near the town of St. Albans, the Kanawha suddenly turns out of the old valley of the Teays and pursues an independent course northwestward toward the Ohio River. The Teays Valley proper, however, continues westward across the remainder of West Virginia. It was this valley that Tight long ago recognized as the abandoned course of a great river. Thick beds of sand and gravel, including water-worn boulders up to twelve inches or more in diameter, lie upon the valley floor. Many, composed of rocks quite dissimilar to the bedrock of the valley, show unmistakably that they were washed by river action from the bedrock region of the Blue Ridge. Only a great and powerful stream could have accomplished this. At places where erosion has removed the river gravels and exposed the bedrock beneath, potholes ground in the bottom of the former channel provide further evidence of the river's course. Along the full length of this broad valley floor runs today the main line of the Chesapeake and Ohio Railroad, its right-of-way selected long ago because it provided the only natural avenue of direct travel through the terrain of the West Virginia hills.

Within the city of Huntington, West Virginia, the abandoned valley of the Teays suddenly ends. Here it joins the stream bed of the more recently formed Ohio River, which enters the city from the northeast. The occupied valley continues toward the northwest, past Ashland, Kentucky, and Ironton, Ohio, to the town of Wheelersburg, about ten miles east of Portsmouth, Ohio, where the Ohio River again leaves it. For this distance of about forty miles, the younger Ohio River has appropriated a portion of the old Teays Valley. Within this section, a major tributary of the Teays, the Big Sandy River, entered from the south. It is still in existence and forms part of the state boundary between West Virginia and Kentucky. Rising on the northwest slopes of the Appalachians, it is now a tributary of the newer Ohio River.

Potholes, ground into the bedrock when pebbles are whirled about by streamwater, have been found in a part of the abandoned Teays Valley in Huntington, West Virginia.

At Wheelersburg the Ohio River leaves the Teays Valley and flows westward to the Mississippi; but the old Teays Valley continues almost directly north past the towns of Piketon and Waverly, between which our newest atomic energy plant is now under construction, and thence on to Chillicothe, Ohio. This section of the Teays Valley is now occupied in part by the Scioto River, which flows south to join the Ohio instead of flowing north as did the Teays. During the Great Ice Age, large amounts of sand and gravel were washed into the valley from the north, thereby reversing the slope of the valley floor.

If one drives northward along the present highway to Chillicothe from the south, he approaches the city through the old Teays Valley. The adjacent hills are rather flat topped, and en masse present an even horizon line against the sky. This skyline level is the western continuation of the vast plateau surface that inclines eastward to the top of the Blue Ridge where the Teays had its source. As one continues toward the city, he sees the distant buildings at a slightly higher elevation, although still within the valley. This gradual rise of the valley floor results from the partial filling of its bottom with glacial sands and gravels, poured into it by the meltwaters from the receding continental glaciers of the Ice Age. The city is built on the surface of this valley fill. The great ice sheets which moved into the United States from Canada during the Pleistocene Epoch advanced almost to the northern edge of Chillicothe.

Continuing northward from the city, the traveler ascends the gradually sloping surface of the valley fill until he is on a vast rolling surface composed of gravelly sand, silt, and clay, which completely bury all vestige of the previous land surfaces over which the glaciers moved. The ice, in its movement over the land, planed off t higher hilltops, filled the valleys with this deb and, in place of the former plateau surface, l a broad, rolling topography which continues the shores of the Great Lakes.

The long valley of the Teays, which can followed from its source in North Carolina, d appears at Chillicothe under the blanket of glac drift. Geologists who first traced the course of t old valley as far as Chillicothe had no means tracing its buried course. Some thought it co tinued northward to the Great Lakes. Oth thought that it turned westwardly into India and met the valley of the Wabash. Indeed, as la as 1943, the lower course of the Wabash w thought to be a continuation of the original Tea Valley.[2]

Knowledge of the actual course of the Tea from Chillicothe to its former mouth at the G of Mexico, has come from the recent study thousands of well records. Such records, in t case of water wells, show the elevation at t present ground surface, the depth to ground wat the type of material penetrated, and, if the w goes deeply enough, the depth of bedrock. Becau of the greater depths of oil and gas wells, addition information about the bedrock becomes availab By plotting the well locations on maps, and sho ing the depth to bedrock for each, the topograp of the preglacial buried land surface has be determined. Thus, it has become known that t general bedrock surface from central Ohio we ward into Illinois represents a continuation b neath the glacial drift of the gently sloping plate surface. In many places the wells have penetrat the drift to depths of 200 to 300 feet deep befo reaching bedrock. The distribution of these deep wells follows a definite pattern and indicates t long winding course of the Teays River fro Chillicothe to southern Illinois.

Not only has the course of the buried river be traced, but the slope of its bed and the width its floodplain have also been learned with reaso able accuracy. At Chillicothe, where the vall floor first becomes lost under the thick deposits glacial material, its elevation above sealevel is 6 feet. As it enters eastern Indiana it is 508 fe and near Lafayette in western Indiana it is 3 feet above sealevel.[2] It continues to drop gradua across Illinois until a minimum elevation of 2 feet is reached where the valley of the Teays again exposed and is occupied today by the linois River. The elevation of the Teays bed its point of discharge into the Gulf of Mexi south of St. Louis is not yet definitely establishe However, at a point fifteen miles south of St. Lou

here the surface elevation is about 400 feet above alevel, bedrock was reached at a depth of 277 et,[3] which would be about 123 feet above sealevel. hether this represents the actual bed of the Teays the bottom of the Gulf of Mexico, which was en becoming filled with delta deposits, cannot t be definitely stated. Sealevel just prior to the reat Ice Age was higher than at present, so that is indicated elevation of the Teays near its mouth ight coincide with the possible sealevel of that me. On the basis of the known elevations of the ver bed between Chillicothe and western Illinois, owever, the Teays River had an average drop of ven inches per mile,[4] which coincides closely with e average gradient of the Mississippi today beween Cairo, Illinois, and its mouth.

The width of the exposed Teays Valley between harleston, West Virginia, and Chillicothe, Ohio, verages about one and one-half miles. The buried ortion gradually widens to about four miles near e Indiana-Illinois line. Near Decatur, Illinois, is about five miles wide, and near Lincoln, where e Teays was joined by the Mississippi, the valley oor broadens to almost fifteen miles.[4] The Teays as a massive and well-established river, as the size d gradient of its buried valley indicate.

The Teays River was dismembered into several maller rivers and partly buried by direct action the great glaciers of the Ice Age. The massive eets of ice which moved into the northern United ates from Canada traveled farther south in estern Ohio, Indiana, and Illinois, than elsehere. The ice extended into northern Kentucky a few places and made its farthest advance in uthern Illinois where the lowest elevations were. he entire lower course of the Teays River below hillicothe was overridden by the ice. The Teays as overridden and all its tributaries within the aciated area were covered.

The well records which have shown the location the buried Teays Valley have indicated the urses of many of the buried tributaries. In so r as these are known, they are shown on the companying map. Most interesting of these was e primeval Mississippi which flowed southward om the border of Canada. Originally it did not ake the big bend around west-central Illinois. stead, its course diverged at Clinton, Iowa, and owed near the middle of Illinois to meet the eays near Lincoln. Farther south, the Teays reived at least one major tributary from the west, e predecessor of the Missouri River, which had somewhat different course than at present and as not so long.

Originating, perhaps, in the days of the dinours, the ancient Teays established its course from

The New River Gorge as seen today from Hawks Nest State Park, West Virginia. Here the river follows the same winding course that it had in ancient times. The nearly level skyline marks the surface of the elevated plateau into which the river has since entrenched its channel. (Photo by U. S. Geological Survey.)

the Blue Ridge to the Gulf. With its great network of tributaries, it helped carve the landscape of a large portion of the continent. The amount of sediment—mud, silt, sand, and pebbles—which it eroded and carried to the sea must have been tremendous. The sea into which it poured those sediments was the long narrow arm of the Gulf of Mexico. This long seaway, from southern Illinois to New Orleans, has been completely filled, and the great delta now juts far into the Gulf proper.

The building of the delta has been attributed to the Mississippi River, which now follows its entire length. This part of the Mississippi, however, has been in existence for a brief time in comparison with that of the former Teays. It seems evident that the greater bulk of the delta was built by the Teays, with the Mississippi adding only the latest portions. Hence, the immense delta, more appropriately, might be called the delta of the Teays.

It is possible that the Teays may have extended its course considerably beyond the point near St. Louis which was originally its mouth, just as the Colorado River has filled the northern end of the Gulf of California, and must today flow over this extended land. If the Teays had accomplished as much as the Colorado in this respect, its lengthened course over the filled land would have extended well beyond Cairo, Illinois. This would mean that it had as an additional tributary the ancestral Ohio River, which then was a relatively small, short river with its source near Cincinnati. If the Teays had extended its course much farther before becoming extinct, it may have had essentially the same additional drainage as does the lower Mississippi today.

The great Teays River ceased to exist as a surface stream with the coming of the vast glaciers of

the Ice Age. For some reason, as yet unknown, the subarctic climates in the North began to deepen. The snows fell more frequently and lasted longer. The temperatures were lowered to the extent that the long winter snows did not all melt in the short summer months. The unmelted snows packed into ice, and as the years passed, the ice fields grew larger. Great mountains of solid ice took form in Greenland, Labrador, central Canada, and the Canadian Rockies. The great weight of the thickening ice caused it to sprawl outward from these centers of accumulation. These behaved like gigantic mounds of stiff molasses, slowly spreading in circumference as more ice continued to gather at the tops of the domes.

Eventually, the ice moving outward from one dome merged with that from another. Finally, all Canada was blanketed with a continuous ice sheet from sea to sea. In the north, the ice moved toward the pole; in the south toward the United States. Covering hill and valley, the blanket of ice grew thicker as it slowly pushed forward. Attaining thicknesses of 10,000 feet, or possibly more, the sliding sheet of ice advanced along an irregularly scalloped front, with great lobes protruding ahead of the main mass. Inching forward over the land, it wrecked everything in its path. The topsoil and underlying mantle of weathered rock were churned and plowed. Chunks of broken rock became frozen into the bottom of the ice, and as these were dragged along by the advancing glacier, they scratched and gouged the barren bedrock over which they moved.

Slowly the vast sheet of ice moved across the region of the Great Lakes. The lakes were not present then, for they were born of the Ice Age. It was then a region of hills and valleys, probably similar to that of southeastern Ohio and West Virginia today, with the streams draining toward the St. Lawrence River. The valleys were deepened and widened and changed in shape; and the materials gouged out of them were carried forward by the advancing ice.

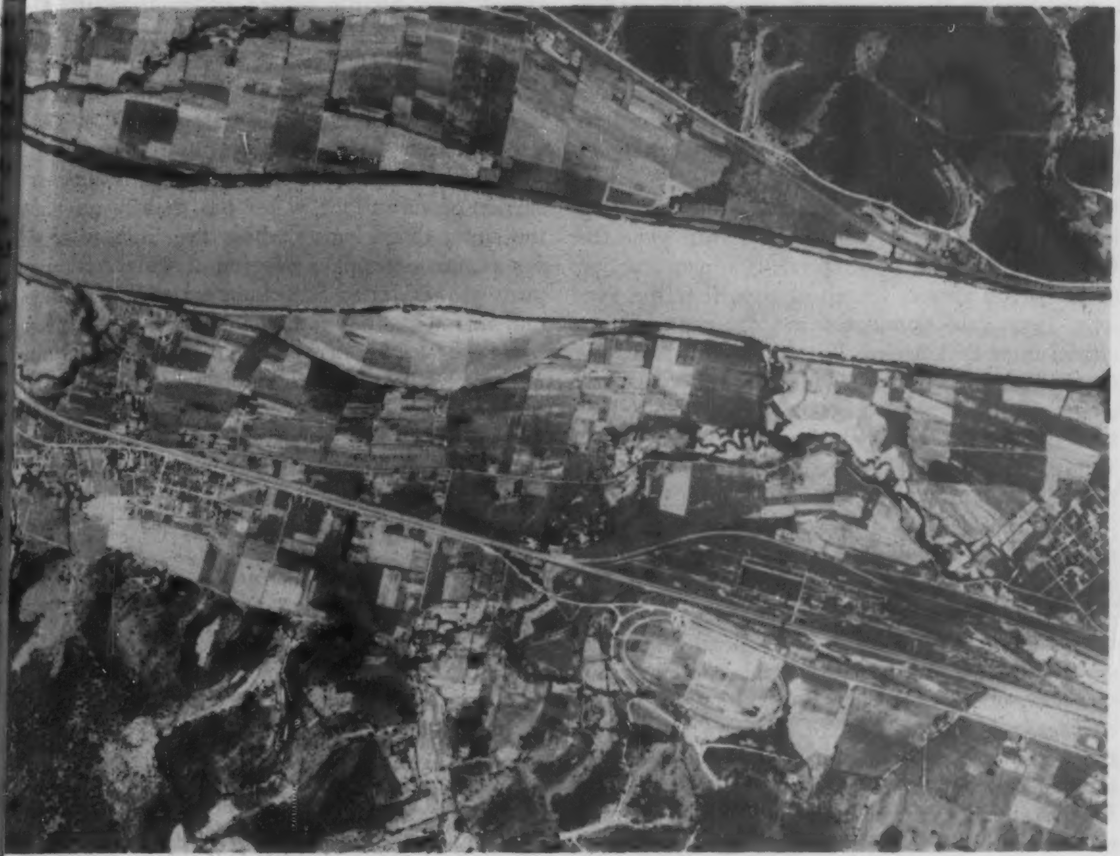
By this time the great mass of ice was overriding the upper Mississippi and encroaching upon other northern tributaries of the Teays. The mammoth, the mastodon, and the musk ox, which had ranged far northward along the shores of Hudson Bay, found themselves migrating ahead of the towering ice sheet. They crossed the Teays River in great numbers. Today we find their fossil bones in Kentucky and West Virginia, and some as far south as Florida and Mexico.

Eventually, the advancing ice reached the banks of the Teays and slowly moved across it, burying both the river and its wide valley beneath blanket of debris. The ice mass inched its w almost to the tip of southern Illinois before stopped. Its irregular front tapered backward each direction, into New England on the East, a into the Montana Rockies on the West.[5] T lower course of the Teays below Chillicothe buried beneath the vast sheet of glacial ice.

The long wall of ice, which now covered t upper course of the river, became a great natu dam beyond which the headwater flow could n penetrate. Consequently the upper waters beca ponded, converting the stream into a long narr lake confined within the valley walls. Thick lay of finely laminated clays deposited in this la bottom indicate that it stood several thousands years before the ice melted and released the pond waters.[6] Perhaps, when the lower course of t Teays had been uncovered, stream waters ag surged through its partially filled valley. On t other hand, if its valley had by then become co pletely filled with glacial debris, it is unlikely th the river ever returned to its previous surfa course.

This much, at least, we do know. The gr glacier, which had moved southward over t Teays and had later melted, was only the first four which followed each other in geologica rapid succession. Each of these advanced along own individual front, so that the points of farth advance do not coincide. In many places, t later ice sheets extended beyond the limits of t earlier ones. Each had the effect of partially completely obliterating the deposits dumped by t preceding ones. In only a few places can all fo successive beds of glacial deposits be found on t of one another. At least two, probably three, a possibly all four of the great glaciers of the I Age overrode some portion of the lower Te Valley. What the first glacier may have failed accomplish was completed by one or another the others. When the last of these glaciers h melted back for the final time, the entire lo valley of the Teays was deeply buried. The val was filled with deposits of gravel, sand, and s and the glacial debris covered the entire landsca the highlands and the former valleys. The avera thickness of the material which now blankets t north-central United States is in the neighborho of fifty or sixty feet.[7] In some places it is thinn in others it is thicker by a hundred feet or mo Below this general depth are the buried vall whose bedrock bottoms sometimes extend seve hundred feet deeper.[8]

The ponding of the river waters, which w



Aerial view of the Ohio River where it cuts diagonally across the valley originally occupied by the Teays River near the outskirts of Russell, Kentucky. (Courtesy of Chesapeake and Ohio Railroad.)

blocked by the ice during one or more of its advances across the valley of the Teays, flooded the main valley above Chillicothe and those of the entering tributaries. Such valleys became long finger lakes. Nearly all the tributaries in southeastern Ohio and adjacent regions of Kentucky and West Virginia, in their lower courses, then held standing water instead of flowing streams. As a result, the bottoms of these temporary lakes, like that of the main Teays Valley, received layers of fine silts and muds that settled out of the water in great thicknesses over the coarser streambed sands and gravels. Eventually, some of these lake waters overflowed their rims, cutting through low divides in the enclosing hills. New systems of drainage evolved, and when these lakes were finally drained by the melting of the glacial dam, stream patterns bearing little resemblance to the former Teays system were in effect.

Portions of the Teays Valley, such as the abandoned section between Huntington and Charleston, West Virginia, as well as similar abandonments in various tributaries, were thereafter cut off from direct connection with the new stream systems. In other cases, the drainages were completely reversed because the glaciers had left the new land surfaces sloping generally southward from the Great Lakes. For example, the Allegheny and Monongahela rivers in Pennsylvania were originally northward-flowing tributaries of the St. Lawrence River, whose headwaters extended into the region of the Great Lakes before the glaciers gouged out those tremendous basins. The direction of their flow was reversed by the advancing ice, and they were made to merge at Pittsburgh, thereby sending a flood of water southward—the start of the modern Ohio River. These waters poured southward toward Huntington where they found the now-abandoned valley of the Teays, which they followed as far as Wheelersburg, Ohio. Additional waters, pouring southward all along the melting front of the glacial ice, added their torrents to the new river. Since the river was prevented from continuing to Chillicothe in the old valley, which now

had a slope in the opposite direction, the waters broke over the low divide to the west and poured into the previously existing lower Ohio Valley which then had its source near Cincinnati. Thus the Ohio River, as we know it today, came into existence, replacing in part the surface system of the Teays.

A million years have passed since the advancing ice of the first great glacier slid down over the valley of the Teays. This represents a mere fraction of the much greater length of time that the age-long Teays had dominated the drainage of preglacial interior America. But during this relatively much shorter time, the ice sheets completely changed the face of the lands over which they moved. They established the Great Lakes, they left 10,000 smaller lakes in Minnesota, they turned the headwaters of the Missouri southward, they pushed the lesser Mississippi to the west, and sent the combined waters of a new river system down across the old delta of the Teays.

In spite of these tremendous changes, the Teays River is not totally extinct. Its headwaters, between North Carolina and central West Virginia, still flow, under different names, along the identical age-old channel. At St. Albans, they were simply diverted to add their flood to the new Ohio. But much more important is the fact that the greater, buried portion of the Teays still carries its waters across Ohio, Indiana, and Illinois. Because it is much easier for rainwaters and melted snow to percolate between the loose sands and gravels that fill the buried valley than it is for them to seep through the bedrock on either side, there remains an avenue for the movement of ground water along the old channel. The Teays River is not really gone; its waters still flow slowly underground.

The discovery of the buried Teays Valley as a carrier of subsurface water has greatly advanced the cause of geologists whose task it is to search for adequate supplies of ground water. In many parts of the United States our expanding economy and increasing population have drawn so heavily upon the supplies of water that many communities and areas have found themselves dangerously short of this basic necessity even when no drouths exist. In the future, geologists concerned with such problems will search for buried river channels with the same diligence that they now search for hidden pools of oil and gas.

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150 YEARS OF ATOMIC PHYSICS

One hundred and fifty years ago (Oct. 3, 1803) John Dalton, in a paper on the solubility of gases in water, made a remark which started the "Modern Atomic Theory." "An inquiry into the relative weights of the ultimate particles of bodies is a subject as far as I know entirely new. I have lately been prosecuting the inquiry with remarkable success. The principle cannot be entered upon in this paper but I shall subjoin the results as far as they appear to be ascertained by my experiments." He then gives a "table of relative weights of the ultimate particles of gases and other bodies," the first table of atomic weights.

Dalton's researches were made available in 1808, when he published his *New System of Chemical Philosophy.* "Therefore, we may conclude that the ultimate particles of all homogeneous bodies are perfectly alike in weight, figure, etc. In other words every particle of water is like every other particle of water: every particle of hydrogen is like every other particle of hydrogen, etc.," (*New System of Chemical Philosophy,* p. 142). (*Discovery,* Vol. 14, No. 10, October, pp. 318–320, 1953, also gives a reading list on the history of the Atomic Theory.)

BOOK REVIEWS

Eugenics: Galton and After. C. P. Blacker. 349 pp. $5.00. Harvard University Press, Cambridge, Mass. 1952.

FOR more than twenty years Dr. Blacker has been General Secretary of the Eugenics Society of London and a frequent adviser to the British Government on population problems. He has written or edited eight previous books, of which *The Chances of Morbid Inheritance* (1935) is perhaps the best known. His long association with and leadership of the eugenics movement in England eminently qualify him to discuss the past and evaluate the present trends in this field.

This book is divided into two parts, of which the first (126 pages) is a brief account of the life and work of Sir Francis Galton, founder of the Eugenics Society. Numerous pertinent quotations from Galton's writings are given. Blacker is particularly interested in describing Galton's personality and his attitudes toward religion, evolution, and eugenics in the Victorian world, in which there were many sharp controversies on these subjects. Galton's many and varied interests in scientific and social fields are discussed, and their startling variety is underscored by an appendix which lists the 227 titles in Galton's personal bibliography.

The second part of this book, entitled "After Galton," describes the development of eugenics after the death of Galton in 1911. The treatment is largely historic, describing developments as a logical outgrowth of Galton's views and emphasizing the debt to these of much current thought on eugenic and population topics. The chapter on population growth is well done, with a simplified description of the demographic cycle and pertinent remarks concerning the "demographic dilemma" which confronts the world today, particularly in reference to the problems of overpopulation in Asia. The discussion of recent developments in testing procedures leaves much to be desired, although the writer reminds us of reservations, qualifications, and difficulties encountered in various types of tests of intelligence, aptitudes, and skills that are all too frequently overlooked, even by those particularly trained in the use of such tests. The chapter on developments in genetics is the longest in the book (50 pages) and gives a brief review of some of the outstanding mileposts reached in the past 50 years, but it is more concerned with a discussion of philosophical aspects of genetic theory than with a presentation of historic fact. Fifteen pages of this chapter are devoted to discussion of "biological science in the USSR," with a description of the development and tenets of Lysenkoism and its opposition to Mendelian genetics. The author exhibits the expected revulsion for the determination of "correct" scientific attitudes by political edict, but seems hopeful that some compromise position based on fact and not on political expediency may eventually be reached in this controversy.

In the two final chapters, Dr. Blacker summarizes his views on eugenics under the title "Eugenics Today." There is discussion of standards of eugenic value, the uses of para-medical services such as marriage guidance, health examinations and birth control, problems of identification of eugenically favored and unfavored families, and of economic measures which could promote the well-being of children. Blacker's conclusions and recommendations for future eugenic progress should probably be accepted as representative of British thought and of the position of the Eugenics Society. His opinions are in many ways similar to those that have been expressed in this country by Frederick Osborn (*Preface to Eugenics*, 1951), and which largely represent the opinions of the American Eugenics Society. As the quality and quantity of its future citizens are certainly among the most valuable natural resources of a nation, these conclusions and recommendations are of outstanding importance and deserving of wide and thoughtful discussion.

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Introduction to Logical Theory. P. F. Strawson. 266 pp. $3.50. Wiley, New York; Methuen, London. 1952.

THIS book has two main aims: to bring out the relations and contrasts between ordinary discourse and formal logic, and to clarify, at an introductory level, the nature of formal logic. It is also intended to include enough elementary material to provide a basis for the study of its philosophical aspects, and to serve as an introduction to more advanced technical treatise.

It begins with a discussion of the logical appraisal of statements in terms of the concept of inconsistency, and continues with an explanation of the object of formal logic, the use of formulae, the notions of logical form and logical system. Then we have a description of the propositional logic in terms of truth functions and truth tables, with some indication of the formulation of this logic as a deductive system. The author passes to the Boolean logic of classes as an alternative interpretation of the same abstract system, and as a part of the logic of propositional functions of one variable. He then treats the Aristotelean logic of classes and shows its consistency and its interpretability in terms of the Boolean logic. After a very sketchy introduction to propositional functions of several variables and the theory of relations, he analyzes in detail the relations between formal logic and the logic of ordinary discourse. He concludes with a chapter on inductive reasoning and probability.

The author falls between two stools in attempting to write simultaneously an introductory book for beginners and an original contribution to the logical analysis of ordinary speech. His effort to take care of the complications due to the vagueness, ellipticity, exceptions, and anomalies of ordinary discourse leads to

an awkwardness and obscurity of style, making the exposition unnecessarily difficult for the uninitiated, while the detailed discussion of some obvious matters in very elementary terms is often rather tedious for the better prepared reader. It leads him to write such sentences as: "Then we can frame our desired general entailments on the following model: any statement made by the use of a sentence which could be obtained by substituting a certain word or phrase for the variable in the formula 'x is twenty-nine years old' entails the statement made by the use in the same context of the sentence obtained by making the same substitution in the formula 'x is under thirty years old'" (p. 30), and "The standard or primary use of an 'if . . . then . . .' sentence, on the other hand, we saw to be in circumstances where, not knowing whether some statement which could be made by the use of a sentence corresponding in a certain way to the first clause of the hypothetical is true or not, or believing it to be false, we nevertheless consider that a step in reasoning from that statement to a statement related in a similar manner to the second clause would be a sound or reasonable step; the second statement also being one of whose truth we are in doubt, or which we believe to be false" (p. 83).

At the same time, the limitation to an elementary exposition prevents him from developing the technical machinery needed to deal with the logical problems of language adequately. The author makes a valiant attempt, and has buried in his book some suggestive ideas. But the reader who patiently tries to dig them out will often be disappointed when the author raises an interesting problem, points out its importance and difficulty, and then makes no serious effort to tackle it.

The book is unsatisfactory as a preparation for further study because of its frequent use of nonstandard terminology and very meager references to the literature. Its insistence on the inadequacies of modern logic and the sins of most other writers on the subject, together with its concentration on matters which, from a beginner's common-sense point of view, would appear to be quibbling over trivialities, will hardly give him an appreciation of the beauty, fascination, and power of modern logical theory, and would, indeed, discourage him from pursuing the subject further.

The working scientist in a nonmathematical field usually becomes interested in logical theory for one of two reasons. He often wants to know the techniques of theory construction—how to organize his ideas into a deductive system, the uses and limitations of such a system, the things to look for and to avoid in such a theory. The author gives no example of a deductive system, nor does he indicate in any way the central importance of such systems in formal logic.

The experimental scientist usually wants the help of the mathematician or logician in the design of experiments or the interpretation of empirical results. He wants, for example, to know whether he is justified in drawing a certain conclusion from his data, or how to test a given hypothesis, or whether he can estimate a certain probability on the basis of his observations. The author, in his last chapter, is primarily concerned with the question: "What reason have we to place reliance on inductive procedures?" (p. 249). He decides that the question arises from confusion, that previous answers are spurious, and that "induction is rational (reasonable)." He does not discuss the problem of how to assess the degree to which a given set of data support a given proposition.

It is unfortunate that the author has overburdened an elementary introduction with matters which more properly belong in a research publication. We hope that he will at least salvage his valuable insights on the logic of language in some future exposition, for experts, of a fully detailed technical treatment.

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Along the Great Rivers. Gordon Cooper. 159 pp. plates. $4.75. Philosophical Library, New York, 1952.

NO matter how many books are written on the world's great rivers, there always seems to be room for one more. Especially is this true when an author speaks from the standpoint of a traveler and reporter as Gordon Cooper does. His latest work appears to be something of a sequel to *Dead Cities and Forgotten Tribes* published a year ago. Both volumes feature people and the things they do, rather than places and statistics.

Name the important rivers that come easiest to mind on each of the continents and the chances are you'll hit most of the ten covered in this book—missing perhaps only one, the Murray, mighty life-line of South Australia and Victoria. The name probably should be hyphenated to include the Darling, for this tributary is as important to Southeastern Australia as the Missouri contribution to the Mississippi-Missouri system is to our own mid-continent states. The author tells the story of how Mildura, Victoria was reclaimed from a desert waste by dispossessing the rabbits and putting to work the millions of gallons of water flowing seaward. All of this happened within about the same time-span wherein U.S. pioneers performed similar miracles in areas of parched America.

On the other hand, the story told in the chapter on the Mississippi is one of floods only partially controlled; of Spanish and French influences still apparent; and of a strange community called Gee's Bend, a remote river spot uninvaded by automobiles or the tax collector until recently.

No one could possibly leave out the Nile in considering rivers that have meant most to men and civilization, nor the Yangtze Kiang, so vital to other untold millions for centuries before Marco Polo saw it, nor the Ganges, Holy River worshipped by India's multitudes.

With Cooper and David Livingston the reader invades Darkest Africa along the Zambezi to Victoria Falls, camps out in the African veldt. The Danube, Highway of Races, is another inescapable topic—Iron Curtain or no. Blue is its color, with poetic license—

muddy grey or dull green in actuality, according to Cooper. History, legend, and stories of commerce help round out the author's personal experiences, mostly in Vienna, the native or adopted home of Strauss, Schubert, Augustin, Gluck, Mozart, Haydn, Beethoven, and Brahms.

In the USSR the Volga was chosen over the longer Ob and Lena rivers, perhaps because almost everyone can appreciate how much the Volga means in the affections of the whole Russian people. Those who are footloose and fancy-free will lament with Cooper that "It seems strange today to realize that only 20 years ago foreigners were welcome visitors to Russia . . . that they could travel about more or less freely, in most parts of the country. You could, for instance, go to Cook's and buy a ticket right through from London to Tokyo, by way of the Trans-Siberian Railway, and you could likewise make a trip down (or up) the Volga."

Include also the St. Lawrence on your list and South America's Amazon, mightiest of all earth's rivers, and you will have duplicated the author's choices for chapter headings. The little volume is an excellent one for inclusion on the reference shelves of school and public libraries, even though it doesn't offer much to scholars and serious students of river lore, river commerce, or science.

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Atoms, Men and God. Paul E. Sabine. x + 226 pp. $3.75. Philosophical Library, New York. 1953.

A research scientist, emotionally conditioned toward religion by having been raised in the home of a Methodist preacher, tries to answer the question, "Can I be intellectually honest in believing what, as a Christian, I profess to believe and at the same time accept the teachings of modern science and psychology regarding the nature of man and God and the physical world?"

While the answer is unquestionably affirmative, the precise nature of the reconciliation achieved is not too clear. In some places the author seems to adopt a Spinozistic position which conceives of the "final stuff" of the world as exhibiting itself under two aspects, physical and psychical. Such a view, of course, makes a place for spiritual values. In others he argues for a conception much like that of Weyl and Jeans, who find God in the world because of the remarkable "fit" which mathematical formulae have. In still other places he seems to accept a somewhat disguised Berkeleyan idealism, "that God and the atoms and the human soul are one in essence, a spiritual trinity, three expressions of the unity of the living Soul of a living universe" (p. 219). And one finds suggestions of Eddington and Compton when he employs the principle of indeterminacy to argue that "choice" is not unmeaningful when applied to the physical world.

The author is obviously sincere, and struggling with what is for him a vital problem. There is little of originality in the work; the "arguments" for the existence of God and the justifiability of religion are those which have been repeatedly discussed in the history of philosophy, and such as one can find, somewhat more carefully formulated, in any good introduction to philosophy.

A. CORNELIUS BENJAMIN
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The Itinerant Ivory Tower. G.E. Hutchison. xi + 261 pp. $4.00. Yale Univ. Press, New Haven, Conn.; Oxford Univ. Press, London. 1953.

A mutual friend tells me that Mr. Hutchison toyed with the idea of calling his book "From a Plastic Tower." I rather wish he had, because a plastic tower sounds like a fresh and personal vantage point from which to view the world. Ivory is anachronistic, even when itinerant. To be sure Mr. Hutchison is anachronistic in some ways in this book. It is a book of essays, and in our plastic world the essay has given way to the article—a substitution that seems more deplorable than the change from ivory.

This is, then, an unusual book. Books by scientists tend to be either summaries of knowledge of a particular field or (rather rarely) popularization hopefully aimed at a wide audience. This is a wide book aimed at a narrow audience. At least the trade publishers would regard it as a relatively narrow audience—literate people with an interest in science and ideas and able, occasionally, to read meditatively. Maybe this audience is larger than the publishers think.

Most of the materials of the book were originally published as "Marginalia" in the *American Scientist*, but they seem to me to read better in book form than in the journal, and I don't think anyone should overlook the book just because he has followed "Marginalia." When the snippets are all strung together they give a much more adequate impression of an unusual and stimulating mind; and the diverse ideas, in close juxtaposition, gain considerably in force.

The word "biogeochemistry" doesn't occur in the book (at least it isn't in the index), though the holistic, biogeochemical point of view is implicit everywhere. There is as much anthropology as biology here, and perhaps more philosophy and criticism (in the old-fashioned meaning of the word). Many stretches of text are pleasantly enhanced by a haze of erudition—at least I found the erudition pleasant. I don't think the author was using the erudition to cover up flaws in his argument, but I don't really care.

A review should probably make some mention of contents; but there is such a diversity here that I don't know how to go about it. There is discussion of bird behavior in relation to psychoanalysis; analysis of Kroeber's too-little-known *Configurations of Culture Growth* and of Huntington's too-well-known *Mainsprings of Civilization*; some rather cutting remarks about the loves discovered in the Yale index cards by Ford and Beach; unreserved tribute to Ruth Benedict and D'Arcy Thompson; reflections on religion as a taboo subject.

My humanist friends often make snooty remarks

about narrow-minded and illiterate scientists. I am going to lend them this book. I think our graduate students often are pretty narrow-minded, and I am going to recommend it to them, too. But I hope I don't lose my copy because I'll be needing it in my own daily living—there are many things here that I aim to crib and pass on to my captive undergraduate audience.

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Succulent Plants: Other Than Cacti. A. Bertrand. 112 pp. Illus. + plates. $4.75. Philosophical Library, New York. 1953.

THIS small and unpretentious work of A. Bertrand has much to recommend it to the amateur who desires to learn something about succulents as well as to grow them. One only wishes he had elaborated a bit more upon the culture as well as the control of pests and diseases. This last, all too often overlooked by the would-be grower, frequently proves costly and disappointing in the loss of plants, and causes many gardeners to give up the growing of succulents as too difficult. Confining the descriptions to the more readily available plants is a wise step, and one which this reviewer wishes would be followed by more writers on similar subjects. The illustrations are excellent and well-chosen and give a good overall view of succulents in general. The descriptions are concise and would serve well to help one recognize the plants to which they refer. In the attempt to bring the nomenclature up to date, a few errors occur, but these need not detract from the unmistakable value of this little book for the beginner who wants to learn about succulent plants.

EDWARD J. ALEXANDER
The New York Botanical Garden

Our Neighbour Worlds. V. A. Firsoff. 336 pp. Illus. + plate. $6.00. Philosophical Library, New York. 1953.

IT is a pity that such entertaining style and generally lucid exposition should be wasted on a book of so little real worth. The author has tried to produce a popular account of present-day knowledge and theories about the solar system, combined with a discussion of the possibilities of space travel. He has read most of the elementary books and a few of the more advanced ones, but has not always understood what he has read. The reader to whom Mr. Firsoff has addressed his book would be well advised to consult the author's sources instead.

Examples of the author's lack of real understanding are to be found in his statement of Kepler's Second Law (p. 26), and his discussion of the sun's orbital motion in the galaxy (p. 18). The phrasing of Kepler's Second Law apparently is original, and that is probably why it is wrong. The velocity of the sun relative to the stars in its neighborhood is said to be its orbital velocity. The actual value is about 10 times larger. The references to "astigmatic lenses" (p. 60), "General Vanderburg" (p. 95), and the "MacDonald Observatory" (p. 292) are probably due to carelessness and not ignorance.

The first four chapters give a general astronomical introduction and a discussion of theories of the origin of the solar system. Firsoff has his own theory, but his discussion of this includes calculations based on a figure for the number of stars in the galaxy (p. 41) which is too small by a factor of 10. The next four chapters are devoted to the possibilities of space travel, and these are followed by six chapters giving a survey of the planets and their satellites, and the asteroids. Comets are ignored, and meteors are discussed in connection with problems of space travel. The final chapter is a mathematical appendix.

Other books by the same author are listed as follows: *Arran with Camera and Sketchbook, The Cairngorms on Foot and Ski, The Tatra Mountains, Ski Track on the Battlefield,* and *The Unity of Europe.* In preparation is: *In the Hills of Breadalbane.* The "blurb" on the jacket of the book describes him as a "fully qualified and practical astronomer." This is a mislabeling of an intellectual product comparable with the mislabeling of worthless, but harmless, drugs and chemicals.

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A Free Society. Mark M. Heald. xii + 546 pp. $4.75. Philosophical Library, New York. 1953.

THE future of democracy may indeed be an article of faith, but it is by no means a certainty. In an ever more complex world where the individual is ever less secure, democracy is being required to repel attacks and dispel doubts under conditions that will tax it to the utmost. The extent of its success will in the long run depend on the capacity of those who cherish it, to re-examine its problems and reconsider its very essence in the light of the new conditions that mark society at mid-century.

These tasks Professor Heald has undertaken in *A Free Society,* not as a contribution to political science but in order "to provide the average citizen of a flourishing democracy with some guides for his thinking with regard to an admittedly confused and paradoxical popular understanding of a vital and practical political concept."

This is a large order and a commendable enterprise to which he brings a thoughtful analysis and a considerable talent for condensation. The book is comprehensive, if necessarily somewhat superficial in places. Attention is given in about equal proportions to the philosophical and historical aspects of democracy and to a description of its present state, its challenges, and the way it can be made to function better and to flourish. Heald has a laudable and understandable conviction about the superior merits of democracy. He is also aware of its imperfections and inconsistencies, its vulnerabilities and dilemmas. Many of the points he makes are well taken; for example, his comments on the prevailing pre-

occupation with security as the prime value in society, the negative attitude of Americans toward political power and the institution of government, or the unsolved problems of economic democracy and the challenge of the welfare state.

Like most of mankind, however, the author is better at describing problems than at offering solutions. Perhaps it is unreasonable to expect more in the way of prescriptions than the exhortations and generalizations he often provides. As a guide to the average citizen the book would be more interesting and of greater value, in any case, had he made more frequent use of specific instances and illustrations throughout. *A Free Society* is nonetheless a thoughtful and a useful general treatment of a vital topic.

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Heredity in Health and Mental Disorder. Franz J. Kallmann. 315 pp. Illus. $6.00. Norton, New York. 1953.

INTEREST in medical genetics is increasing all the time, and nowhere is that interest more intense than in the area of mental health and mental disorder. The author of this volume has spent twenty-five years in research on schizophrenia and other forms of mental anomalies, and for sixteen of those years has developed the Department of Medical Genetics at the New York State Psychiatric Institute. He is best known for his formulation of the twin-family methods of investigation.

The book is in three major parts. The first section deals with the general principles and methods of human heredity. It is clearly and interestingly written and provides a valuable introduction to the more technical matter of the following sections. Part Two discusses heredity in relation to specific mental disorders. Many case histories from the personal files of the author are presented, to illustrate clearly the principles and conclusions at which he arrives. The author rightly insists on a sharp differentiation between schizophrenia and manic-depressive psychosis, which have been thought by some to be either clinically or genetically related. Evidence is presented for the dependence of manic-depressive psychosis on a dominant gene substitution with incomplete penetrance. In schizophrenia, on the other hand, a recessive gene appears to be involved. The chance of developing schizophrenia increases in direct proportion to the degree of blood relationship to a schizophrenic individual: about one per cent if no relatives are known to have the disorder, 7 per cent for a half brother or sister, 14 per cent for a full brother or sister, or a fraternal twin, or one parent; and 86 per cent for a schizophrenic identical twin.

Also discussed are involutional psychoses, senile psychoses, epilepsy, and neurological disorders such as amaurotic idiocy, paralysis agitans, Huntington's chorea, and diffuse cerebral sclerosis. The author is not convinced that the dominant gene hypothesis for cerebral dysrhythmia, as shown on electroencephalograph records for epilepsy, is fully substantiated.

The final section is devoted to a very fine discussion of the applications of genetics in mental health planning. All counselors, psychiatrists, and others who are called on for family guidance should read this part carefully. It is very well done. The book is copiously illustrated throughout and is finely printed and bound.

LAURENCE H. SNYDER

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The End of the World: A Scientific Inquiry. Kenneth Heuer. 220 pp. Plates. $3.00. Rinehart, New York. 1953.

SEVERAL years ago a Moscow astronomer, A. Vorontzoff-Veliaminov, criticizing the description of the possible future explosion of our sun given in a book by L. Goldberg and L. H. Aller, wrote: "The purpose of such realistic descriptions in the capitalistic world is to prove the futility of the life on the Earth, and to undermine the will of the people to rebuild their social order." Judging by these standards, the recent book by Kenneth Heuer represents supercapitalistic propaganda, since from the beginning to the end it discusses all thinkable, and a few unthinkable, ways in which our little planet might meet its doom. Heuer does so in very vivid, realistic language supported by a number of impressive illustrations. The book contains a large amount of interesting historical information concerning historical predictions of the end of the world. We learn, for example, that, according to Bernard, a hermit of Thuringia, the end of the world was due in A.D. 992, the year when the Annunciation of the Virgin fell on the same day as Good Friday. This year passed, and the world still continued! According to Nostradamus, the king of astrologers, the end of the world had to come on the day when Easter Sunday would fall on St. Mark's day (i.e., April 25th). It is amusing to learn that, according to the calendar accepted in Nostradamus' time, such a coincidence was absolutely impossible, but it became possible according to the new (Georgian) calendar introduced in 1582, twenty-six years after Nostradamus' death. The next danger-day to watch is April 25th, 2038!

Having covered the historical background of the problem, the author turns to the world catastrophes which could be expected on the basis of strictly scientific astronomical data. He considers the possibility of a collision of the Earth with the head of a comet, which, without destroying our globe, might cause damage comparable to an atomic bomber's attack in intercontinental warfare. Heuer refers to astronomical calculations which show that in some year A.D. 50,000,000,000+ the moon will approach very close to the Earth, and, being broken into a thousand pieces, will stone the surface of our planet by rocks as large as mountains. He also considers the eventuality of a star encountering our solar system and either colliding with the sun itself, or at least kidnapping and carrying away with it our poor Earth. Although all such perils of collision possess exceedingly small probabilities, they are all in principle possible,

and might happen either within the near or the distant future.

In subsequent chapters, the author turns his attention to the future of the Earth that would result from the future evolutionary history of our sun. He gives a vivid description of boiling oceans and melting rocks in the case of a nova-like explosion of the sun, and paints a severe picture of Ice-bound Rio de Janeiro in the case of the sun's thermal death.

K. Heuer's book came out a little too early to include the most recent views on solar evolution, according to which, in a few billion years from now, our sun is bound to expand into a red super-giant, gradually engulfing in its slowly swelling body the system of inner planets to which it once gave birth. It seems, in fact, that such an expansion will precede the explosion itself, and subsequent cooling.

Having dealt with all natural causes that may terminate life on the surface of our planet, the author turns his attention to the "man-made end of the world." He quotes the experts in atomic explosions to the effect that all life on the earth can be completely destroyed by a number of hydrogen bombs that could be produced by a major industrial nation in the course of five to ten years, and at a cost of only $40,000,000,000. This certainly looks like a much more reasonable way of destroying humanity than all the astronomical stuff!

On the whole, the book represents a very amusing, instructive, and exciting reading.

G. Gamow

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Books Reviewed In SCIENCE

November 6

The Human Senses. Frank A. Geldard. New York: Wiley; London: Chapman & Hall, 1953. 365 pp. Illus. $5.00.
Reviewed by William R. Amberson.

Starch: Its Sources, Production and Uses. Charles Andrew Brautlecht. New York: Reinhold, 1953. 408 pp. Illus. $10.00.
Reviewed by Roy L. Whistler.

Psychiatric Dictionary. With encyclopedic treatment of modern terms. 2nd ed. Leland E. Hinsie and Jacob Shatzky. New York: Oxford Univ. Press, 1953. 781 pp. $15.00.
Reviewed by G. N. Raines.

November 13

Human Behavior: Psychology as a Bio-Social Science. Lawrence E. Cole. Yonkers-on-the-Hudson, N. Y.: World Book, 1953. 884 pp. Illus. $5.50.
Reviewed by Melford E. Spiro.

Praktische Arbeitsphysiologie (Applied Physiology of Human Work). Gunther Lehmann. Stuttgart: Georg Thieme, 1953. (U. S. distrib.: Grune and Stratton, New York.) 355 pp. DM 33.
Reviewed by Josef Brožek.

November 20

Undtersuchungen über die Tiergemeinschaften des Bodens: Die Oribatiden und ihre Synusien in den Böden Norddeutschlands. Karl Strenzke. *Zoologica,* Band 37, Heft 104, Stuttgart, 1952. 172 pp.
Reviewed by Edward W. Baker.

The Sulfapyrimidines. Lawrence H. Sophian, David L. Piper, and George H. Schneller. New York: A. Colish, for the Lederle Laboratories, 1952. 180 pp.
Reviewed by E. E. Campaigne.

Visceral Circulation. A Ciba Foundation Symposium. G. E. Wolstenholme, Ed., with assistance of Margaret P. Cameron and Jessie S. Freeman. Boston: Little, Brown, 1953. 278 pp. Illus. + plates. $6.50.
Reviewed by Frederick P. Ferguson.

Deformation and Flow in Biological Systems. A. Frey-Wyssling, Ed. Amsterdam: North-Holland Pub.; New York: Interscience, 1952. 552 pp. $11.50.
Reviewed by L. J. Mullins.

November 27

Symposium on Chromosome Breakage. (Suppl. to *Heredity,* 6 [1953]). Held at the John Innes Horticultural Institution, June 9–11, 1952. London-Edinburgh: Oliver & Boyd, 1953. 315 pp. Illus. + plates. $7.50.
Reviewed by Karl Sax.

Stochastic Processes. J. L. Dobb. New York: Wiley; London: Chapman & Hall, 1953. 654 pp. $10.00.
Reviewed by D. ter Haar.

Inorganic Thermogravimetric Analysis. Clément Duval. Amsterdam-Houston: Elsevier, 1953. 548 pp. Illus. $11.00.
Reviewed by Thos. De Vries.

LETTERS

LESS AIMLESSNESS IN EDUCATION*

FIRST, I wish to mention two peripheral items in the article. One is the rigging of questionnaires in such manner that unwanted responses are not possible. Unfortunately it is a trick that is not unknown in other educational surveys and, of course, it is not to be condoned. Indeed, the questionnaire method itself, even when honestly used, has its limitations in serious research. There is frequently a temptation to regard as true and right anything that a majority of respondents to a questionnaire believe. But "truth cannot be manufactured from error, no matter how often it is repeated."

The other preliminary comment is on Dr. Bestor's castigation of the "educational bureaucracy," composed of state departments of education, colleges of education, and some voluntary organizations like accrediting agencies. It is true that some of these have arrogated to themselves unwarranted extra-legal powers to set up educational requirements, including such things as standards for teacher certification. For example, there is a teacher who secured a temporary permit from the state department of education to teach safe driving classes. After teaching such classes successfully for three years, he could secure a renewal of his permit only by taking summer school courses in fire prevention and in the prevention of industrial accidents! Ridiculous regulations like this should soon bring an exposure of the intricate operations they resort to for increasing their bureaucratic control.

To turn now to the main theme of the article—aimlessness in education—it should be noted that the appearance of aimlessness results not so much from lack of purpose as from uncertainty in the incomplete process of adapting secondary education to changing conditions. Besides this, the contradictions posed by Dr. Bestor are more apparent in educational theory than in classroom practices.

A number of historical developments in secondary education contribute to this present puzzle. For the purpose of brevity and simplicity, only a few of them will be treated. It is an oversimplification to regard these developments as having occurred in a brief space of time, near the turn of the century. But for the purpose of making clearer their interaction one upon another, they may be regarded as nearly contemporary occurrences.

The first in importance and the longest continuing is the gradual increasing enrollment in secondary schools. In 1900 less than half of the boys and girls aged fourteen to seventeen were in school. Now, after fifty years of expanding secondary enrollment, close to 80% of this age group are in school. The most rapid increase came early in the century. It was not caused by a sudden thirst for knowledge on the part of numerous adolescents but by the rising standard of living. Higher personal incomes now enabled more families to give leisure to their young people and to excuse them from wage earning or from helping on the farm while they went to school.

This great expansion of the secondary school population was more than an increase in numbers. It was also the coming of a different type of pupil. Up to this time the secondary school had existed chiefly for only one purpose, namely, preparation for college. Only the very brightest and ablest of the young people, whose parents at the same time had the means to contribute to their support during their student years, were encouraged to continue their education into high school. Those who could not maintain the pace of Latin, mathematics, history, and science for four years dropped out. Those who survived were the screened best, acquiring that "intellectual discipline" of which Dr. Bestor writes so wistfully. For two and a half centuries secondary education was of this sort—college preparatory. In the course of the years it became standardized and formalized. It was this kind of education to which some of our country's ablest leaders and greatest thinkers attributed their success. But probably it was more consequential that the educational system had screened and selected the top level of intellectual ability. Now with the big expansion of secondary education, the screening was less fine and more young people stayed in high school even though they had no plans to go to college. Their parents demanded for them something besides preparation for college. They demanded "practical subjects."

This was the second factor contributing to the present confusion. A "new curriculum" was developed, mostly under popular pressure. The demand was not only for utilitarian subjects but also for less difficult academic disciplines, such as general mathematics, general history, general science, and citizenship. In 1917 the Smith-Hughes Act passed Congress, providing for federal aid for instruction in manual training, agriculture, home economics, and other vocational courses. Thousands of public schools in even the small towns across the country took advantage of the new law. As the percentage of teen-agers that stayed in school increased, the average intelligence quotient of the school population declined. Other practical and easy courses were added to the curriculum until today there is proposed "life adjustment education." The old uniform college preparatory curriculum gave way to the elective system in most high schools, where the offerings were arranged in groups of required and elective subjects. Now the secondary school assumed a dual purpose. In addition to preparing for college, it also undertook to educate pupils who were not destined for higher education. There was uncertainty about what this second purpose should be. Prep-

* A comment on the article, "Aimlessness in Education," by Dr. Arthur E. Bestor, Jr., *The Scientific Monthly*, 75, 109 (1952).

aration for life came to be the concept preferred over preparation for a vocation. Later it was citizenship that received wide emphasis as the new purpose, or character training. Recently it has become life adjustment.

The third development was new knowledge about the psychology of learning. In support of the old curriculum there had flourished the "theory of formal discipline." It was the name given to the belief that the mind, like a muscle, could be strengthened or developed by exercise on hard subjects, and that then the newly acquired power could be transferred to new and different problems. It was also known as the "transfer of training." The mind was to be disciplined and made strong on school subjects and the strength was in later life to be transferred to any kind of problem. The harder the school subjects, the stronger the mind was supposed to grow.

When psychological research and testing were applied to this theory it was found wanting. Experiments did not uphold it. Some transfer of training was indeed found to occur, but scarcely any was found in pupils with low intelligence. The brighter the pupil, the greater was the amount of transfer. Thus it became more profitable for those of lower ability to concentrate on specific learnings rather than to strive for general intellectual discipline. This new point of view further promoted the offering of vocational and utilitarian subjects with their specific knowledge and skills. And the high school was confirmed in its dual purpose, offering intellectual discipline to abler pupils who could affect a transfer of training, and life adjustment education to the less able.

The final development to be considered is the influence of John Dewey and the "Progressive Education" movement. Briefly, the emphasis was to be turned to the child instead of the subject, to the importance of interest in learning, and to learning-by-doing. The forces that seemed to be forming to divide educational interests into a classical party and a vocational party were now greatly accelerated. Soon a conservative party supplied vigorous opposition to the "Progressives," upholding formal discipline and the traditional curriculum. One faction later went in for the "great books." Through the years the slogans of the two parties varied more than their steady vehemence. Once they were "indoctrination" vs. "freedom"; at another time "competence in subject matter" vs. "the child centered school"; or "essentialism" vs. "the activity curriculum"; more recently they have been "the three R's" vs. "life adjustment education." The spokesmen in the controversy pulled no punches, not stopping short of overstatement and exaggeration and thus causing the apparent aimlessness. To the confusion of many laymen, they often spoke and wrote as if they expected that their views were to prevail in all education, regardless of the level of pupils' intelligence. In the article under consideration, Dr. Bestor seems to wish all pupils, the bright and the dull, to have sound "intellectual discipline." The writer of the Illinois Secondary School Curriculum Program,* as well as A. H. Lauchner,† both of whom Dr. Bestor refutes, write as if they expected that all pupils, both the bright and the dull, are to be given such pap as the 55 problems listed in the Illinois curriculum bulletin.

* Illinois Secondary School Curriculum Program, Bulletins Nos. 9, 10, 11, 13.

The key to the reconciliation and interpretation of these two points of view is the dual purpose of American secondary education. It is also the key to less aimlessness. The same school has the brilliant youth who seeks intellectual discipline adequate for his coming college studies and his later life career, as well as those with meager mental endowment, some of whom can scarcely learn to read and for whom even life adjustment problems will be a challenge. To be true to its dual purpose the school must adjust its curriculum to both levels of ability. In Europe the accepted way of meeting this problem has been to establish separate schools for different abilities, and secondary education has there remained highly selective. But in the United States it has been considered more democratic to provide one school for all pupils and within that school to make the needed adaptations to varying abilities. As exceptions, in the larger centers of population some technical and vocational schools are operated, as is also the Bronx High School of Science for the mentally gifted. Undisturbed by educational controversy, the private secondary schools pursue their single aim, select their students, and prepare them for college. But for the most part, the public secondary schools throughout the land continue to receive in democratic mingling all the children of all the people and must continue to apply the principles of both sides of the controversy in the effort to adapt their instruction to those who have received ten talents and to those who have received one talent.

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† Lauchner, A. H. "How Can the Junior High School Curriculum Be Improved?" Bulletin, National Association of Secondary School Principals, Vol. 35, No. 177, March 1951.

THE QUAESITUM

The very able article entitled "On Absolute Measurement" by N. Ernest Dorsey and Churchill Eisenhart consists of extracts from a book by Dorsey, selected and arranged by Eisenhart. It is full of sound advice to the experimentalist but is founded upon notions of an absolute that have been foreign to the thinking of many people for half a century.

To begin with, the ordinary number system in terms of which measurements are made is a creation of man. To give it a position more fundamental than any other part of man's language is to overlook its basic nature. It was made by man for man's necessities; first counting, then measurement, and then the solution of algebraic equations.

What do we mean by the velocity of light? As commonly understood, we mean a number which we get when we do so and so. It is read as centimeters per second, if you will. What meaning can possibly be assigned to the term apart from human action? A value is used by us which has been reached by a chain of experi-

ents acceptable to present-day scientists. To talk of elocity of light apart from man's operations is simply making a noise. The absolute vanishes when viewed critically here as in other places in science. Physicists commonly speak of the temperature "absolute zero." Here the term absolute must be regarded as a name in every way similar to centigrade. No matter how the physicist may define absolute zero, its determination will lead back to measurements by man, and consequently is not only subject to what we may call experimental errors but subject also to the general mutability of human ideas.

The assumption that any kind of average of a sequence of numerical measurements will approach a limit when the number of experiments is increased seems naive in the extreme. In fact, the very word "limit" when we are considering experiments in science is subject to challenge. Certainly the man who uses it must state what meaning he is attaching to the term. Its use according to the accepted mathematical definition when applied to a set of experiments is non-sense.

The value of the mathematical limit in statistical studies of experimental data may be clarified to those who have not carefully considered the matter by the following brief remarks on the applicability of numbers and mathematical processes to physical science. Here the term "physical science" is to be construed very broadly and is to include much not usually described by the word, physical. A mathematical system starts with a set of undefined terms and certain postulates about them. There follow strings of theorems formed according to a certain logic, that is, according to an agreed set of rules. Now if a physical system consists of a set of objects which can be put into one-to-one correspondence with the undefined terms of a mathematical system and if these objects obey certain laws which can be put into one-to-one correspondence with the postulates of the mathematical system, we say that the physical system is isomorphic to the mathematical system. Applications of mathematics step into the picture. Theorems say: If you do thus and so, you will get so and so. Now are physical systems ever truly isomorphic to mathematical systems? Certainly not, if the mathematical system contains the infinite in any form and this includes the continuous. The simplest physical law, such as $pv = \text{constant}$, is at best an approximate description for certain experimental results and then its usefulness is assumed for limited ranges of the variables only. The assumption that p and v as continuous variables "really" obey this law assumes a fundamentalist definition of p and v apart from human action. "Faith" of this type may have its place in religion but is strictly without meaning in physics. Of course, formulas may be set up to cover a finite set of data. It may then prove to be more convenient to use limiting forms for these formulas obtained by strictly mathematical means. This is commonly done and has been most useful in many types of study. The worker should keep in mind that he is working with a mathematical construct only. For example, the entire subject of calculus in applied science is of this nature. No person in his right mind when working with calculus should assume that its rules are obeyed by a "divine" quaesitum.

It is not proposed to say to what degree it may be profitable for a worker to talk about limits in other than a mathematical sense and about quaesita. He should, however, have a clear realization of what he is doing and of the fact that physical science is not absolute.

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FATHER OF AMERICAN ANTHROPOLOGY

READERS of the very interesting diary kept by William Fellowes Morgan of a portion of his anthropological trip to the Southwest in 1878, edited by Professor Temple R. Hollcroft in THE SCIENTIFIC MONTHLY for September, 1953, may be interested to learn that a journal of the same trip kept by William Fellowes' "Uncle Lewis", Lewis Henry Morgan, was edited and published by the undersigned in *American Antiquity*, **8**, 1, 1942. The elder Morgan's journal was begun on June 21 at Canyon City on the way to southwestern Colorado. It ended at Taos Pueblo on August 7th, the day after William Fellowes' Journal began. The two journals thus provide an account of almost the entire trip.

It may be of interest, also, to note that Lewis H. Morgan, the "Father of American Anthropology," and President of the AAAS in 1880, made four ethnological field trips into the Great Plains and to Hudson's Bay territory between 1859 and 1862. The fourth of these trips was made by steamboat up the Missouri River as far as the Rocky Mountains. A brief account of these expeditions, based upon Morgan's journals, was published by the undersigned in *American Anthropologist*, **53**, 11, 1951: "Lewis H. Morgan's Western Field Trips."

LESLIE A. WHITE

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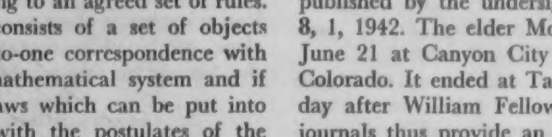

ASSOCIATION AFFAIRS

PREVIEW OF THE 120TH MEETING, AAAS, BOSTON, DECEMBER 26–31, 1953

From advance registrations and Boston hotel reservation data, it is already evident that the 120th meeting of the American Association for the Advancement of Science will be both diversified and well attended—in the latter, quite possibly second only to the record-breaking New York meeting of 1949. Not only will all parts of the continent be represented, but a larger than usual number of distinguished foreign scientists will participate.

An inspection of the General Program-Directory, which is being sent advance registrants by first class mail at this time, shows that the 120th meeting of the Association will combine many traditional aspects and will also have several new features.

Special Sessions. One of the characteristic and most important features of the annual meetings of the Association is the series of outstanding general addresses by distinguished authorities, sponsored by organizations that meet regularly with the AAAS. These special events are joint sessions with the Association and are open to the general public of the city in which the meeting is held.

I. **Sunday evening, Dec. 27, Ballroom, Hotel Statler; 8:00 p.m.** American Association for the Advancement of Science and the Society of the Sigma Xi.

Speaker: A. V. Hill, Foulerton Research Professor of the Royal Society, University College, London, London, England; past president, British Association for the Advancement of Science.

Subject: The Design and Mechanism of Muscle (Illustrated).

Detlev W. Bronk, president, Rockefeller Institute for Medical Research, and chairman of the Board of Directors of the Association; and Lewis J. Stadler, professor of field crops, University of Missouri, president of the Society, will serve as cochairmen.

II. **Sunday evening, Dec. 27, Grand Hall, Mechanics Building; 8:30 p.m.** National Geographic Society.

Speaker: Luis Marden, member, Foreign Editorial Staff, National Geographic Society.

Subject: Sicily, the Forgotten Island (Illustrated).

Meredith F. Burrill, vice president for AAAS Section E, will preside.

III. **Monday evening, Dec. 28, Ballroom, Hotel Statler; 8:00 p.m.** AAAS Presidential Address.

Speaker: Detlev W. Bronk, president, Rockefeller Institute for Medical Research, and retiring president of the Association.

Subject: The Role of Scientists in the Furtherance of Science.

Edward U. Condon, director of research, Corning Glass Works, and president of the Association, will preside.

Preceding the address, Earl P. Stevenson, president, Arthur D. Little, Inc., and general chairman, seventh Boston meeting, will speak briefly.

Following the address there will be an informal AAAS Presidential Reception in the adjacent Ballroom Assembly. All registrants and members of local committees are cordially invited to attend.

IV. **Tuesday evening, Dec. 29, Ballroom, Hotel Statler; 8:00 p.m.** Scientific Research Society of America.

Joseph W. Barker, Research Corporation, president of the Society will preside.

Speaker: David B. Steinman, consulting engineer, New York, New York.

Subject: Suspension Bridges—The Aerodynamic Problem and Its Solution (Illustrated).

V. **Wednesday evening, Dec. 30, Georgian Room, Hotel Statler; 8:30 p.m.** United Chapters of Phi Beta Kappa.

Speaker: Leonard Carmichael, secretary, Smithsonian Institution.

Subject: Science and Social Conservatism.

Kirtley F. Mather, professor of geology, Harvard University, will preside. Warren Weaver, president elect, will represent the Association.

The Scientist in American Society. Early in the year a committee of Section K and the AAAS Symposium Committee, without knowledge of each other's plans both decided that there should be a program on some of the social and political problems confronting American scientists at the present time. The following 2 sessions, combined by mutual consent, are sponsored by the Association as a whole:

Sunday Afternoon, December 27

2:30 p.m.; Talbot Hall, Mechanics Building; *Symposium: The Scientist in American Society, Part I: Freedom for Scientific Inquiry.* Arranged by a committee of Section K-Social and Economic Sciences, Conrad Taeuber, assistant director, Bureau of the Census, secretary.

Detlev W. Bronk, *presiding*

1. The Beliefs and Expectations of the Public. Clyde W. Hart, Herbert Hyman, Paul B. Sheatsley, and Shirley A. Star, National Opinion Research Center, Chicago, Ill.
2. The Social Psychology of Political Loyalty in Liberal and Totalitarian Societies. Raymond A. Bauer, lecturer on social psychology and research associate, Russian Research Center, Harvard University.

Tuesday Evening, December 29

8:00 p.m.; Paul Revere Hall, Mechanics Building; *Symposium: The Scientist in American Society, Part II.* Arranged by a subcommittee of the AAAS Symposium Committee: Charles D. Coryell, professor of chemistry, Massachusetts Institute of Technology, chairman, P. M. Morse, and V. F. Weisskopf, professors of physics, Massachusetts Institute of Technology, and Bart J. Bok, associate director, Harvard Observatory.

EDWARD U. CONDON, *presiding*

1. The Need for and the Production of Scientists. HAROLD C. UREY, distinguished service professor of chemistry, University of Chicago.
2. Scientists and Other Citizens. GERARD PIEL, publisher, *The Scientific American.*
3. The Legal Basis for Intellectual Freedom. MARK DE WOLFE HOWE, professor of law, Harvard University.
4. Scientists and Political Action. EDWIN C. KEMBLE, professor of physics, Harvard University.
5. Discussion, led by EDWARD U. CONDON, director of research, Corning Glass Works.

The AAAS Science Theatre, a permanent feature of he Association's annual meeting, presents showings of he latest domestic and foreign scientific films—nearly ll with sound—throughout the meeting period.

The Science Theatre is a feature for the pleasure and nformation of all registrants attending the annual neeting. It cannot be for the casual passerby; thus **dmission is restricted to those who wear the AAAS onvention badge,** or who show an Association registraion receipt.

PROGRAM 1

unday Afternoon, Dec. 27, 2:00 p.m.–6:00 p.m.

1. CHEMICAL BRUSH CONTROL. American Museum of Natural History. Color. Sound. 23 min.
2. DEMONSTRATIONS IN PERCEPTION. United States Navy. Black-and-white. Sound. 30 min.
3. DECISION FOR CHEMISTRY. Monsanto Chemical Company. Black-and-white. Sound. 35 min.
4. LOCOMOTION OF SNAKES. New York Zoological Society. Color. Sound. 11 min.
5. GENETICS AND BEHAVIOR. Joseph J. Antonitis and J. P. Scott. Color. Silent. 16 min.
6. RADIOISOTOPES: THEIR APPLICATIONS TO HUMANS. Medical Film Guild, Ltd. Color. Sound. 32 min.
7. THE CHAIN OF LIFE. Pictura Films Corporation. Color. Sound. 11 min.
8. PROMINENCE ACTIVITY. Sacramento Peak Station of Harvard College Observatory, Sunspot, N. M. Black-and-white. Silent. 15 min.
9. LIVES OF THEIR OWN. Pictura Films Corporation. Color. Sound. 11 min.
10. MAN TO MAN. Mental Health Film Board. Black-and-white. Sound. 30 min.
11. BETTER AND SAFER HIGHWAYS. The Firestone Tire and Rubber Company. Black-and-white. Sound. 7 min.

Repeated as PROGRAM 4, **Dec. 29, 9:00 a.m.–1:00 p.m.**

PROGRAM 2

Monday Morning, Dec. 28, 9:00 a.m.–1:00 p.m.

1. WARNING SHADOW. National Cancer Institute and American Cancer Society. Color. Sound. 21 min.
2. LEONARDO DA VINCI. Pictura Films Corporation. Color. Sound. 68 min.
3. ANTARCTIC VIGIL. Australian News and Information Bureau. Color. Sound. 10 min.
4. SEE HOW THEY SWIM. Pictura Films Corporation. Color. Sound. 11 min.
5. TARGET NEVADA. Department of Defense. Color. Sound. 14 min.
6. WHICH FATE. National Society for Medical Research. Color. Sound. 28 min.
7. WATERS OF COWEETA. Forest Service, U.S.D.A. Color. Sound. 20 min.
8. WHITE SPLENDOR. Pictura Films Corporation. Color. Sound. 11 min.
9. HIGH QUALITY SPICULES AND CHROMOSPHERE. Sacramento Peak Station of Harvard College Observatory, Sunspot, N. M. Black-and-white. Silent. 15 min.
10. PROJECT TINKERTOY. National Bureau of Standards. Black-and-white. Sound. 27 min.

Repeated as PROGRAM 5, **Dec. 29, 2:00 p.m.–6:00 p.m.**

PROGRAM 3

Monday Afternoon, Dec. 28, 2:00 p.m.–6:00 p.m.

1. THIS IS MAGNESIUM. Bureau of Mines. Black-and-white. Sound. 15 min.
2. AUTONOMIC NERVOUS SYSTEM, PARTS III AND IV. J. E. Markee and R. F. Becker, Duke University. Color. Sound. 42 min.
3. SEE HOW THEY FLY. Pictura Films Corporation. Color. Sound. 11 min.
4. OAK WILT. National Oak Wilt Research Committee. Color. Sound. 22 min.
5. VOICES UNDER THE SEA. British Information Services. Black-and-white. Sound. 19 min.
6. THE EFFECT OF ELECTRO-CONVULSIVE SHOCK ON "CONDITIONED ANXIETY." H. F. Hunt and J. V. Brady. Color. Silent. 14 min.
7. BIRTH OF AN OIL FIELD. Shell Oil Company. Color. Sound. 11 min.
8. KING OF THE RIVER. Pictura Films Corporation. Color. Sound. 11 min.
9. LIFE STORY OF A WATER MOLD. Arthur T. Brice-Phase Films. Black-and-white. Sound. 11 min.
10. "A" IS FOR ATOM. General Electric Company. Color. Sound. 16 min.
11. NEW FRONTIERS IN SPACE. McGraw-Hill Book Co., Text-Film Dept. Black-and-white. Sound. 25 min.

Repeated as PROGRAM 6, **Dec. 30, 8:00 a.m.–noon**

PROGRAM 7

Wednesday Afternoon, Dec. 30, noon–4:00 p.m.

1. LIVING WATER SERIES, PART I: NATURE'S PLAN. Conservation Foundation. Color. Sound. 30 min.
2. RADIOISOTOPES, PART XII: AGRICULTURAL RESEARCH. Department of the Army. Black-and-white. Sound. 40 min.
3. THE SEA LAMPREY. Fish and Wildlife Service. Color. Sound. 13 min.
4. BATTLE OF THE BEETLES. Forest Service, U.S.D.A. Color. Sound. 16 min.
5. SAND AND FLAME. General Motors Corporation. Black-and-white. Sound. 20 min.
6. FLYING DOCTOR. Australian News and Information Bureau. Black-and-white. Sound. 11 min.
7. THE MECHANICAL INTEREST AND ABILITY OF A HOME-RAISED CHIMPANZEE. Keith J. Hayes and Catherine Hayes, Yerkes Laboratories of Primate Biology. Black-and-white. Silent. 60 min.
8. THE QUESTING MIND. General Motors Corporation. Color. Sound. 20 min.
9. WOODCOCK. Fish and Wildlife Service. Color. Sound. 14 min.

INDEX TO VOLUME LXXVII (JULY–DECEMBER 1953)

Title Index of Articles

Subject Index

Contributors

Books Reviewed

Book Reviewers

Verse

Letters

New Books Received

The Itinerant Ivory Tower: Scientific and Literary Essays. G. E. Hutchinson. xi + 261 pp. $4.00. Yale University Press, New Haven, Conn., Oxford University Press, London. 1953.

The Works of Archimedes. T. L. Heath, Ed. With a supplement: The Method of Archimedes. clxxxvi + 377 pp. Illus. Paper: $1.95; cloth: $4.95. Dover, New York. 1953.

Twenty Years of Psychoanalysis. A symposium in celebration of the twentieth anniversary of the Chicago Institute for Psychoanalysis. Franz Alexander and Helen Ross, Eds. 309 pp. $3.75. Norton, New York. 1953.

Ultra High Frequency Propagation. Henry R. Reed and Carl M. Russell. xiv + 562 pp. Illus. Wiley, New York, Chapman & Hall, London. 1953. $9.50.

Target: Earth. The role of large meteors in earth science. Allan O. Kelly and Frank Dachille. v + 263 pp. Illus. + plates. $5.90. Pensacola Engraving Co., Pensacola, Fla. 1953.

Sex and the Nature of Things. N. J. Berrill. xi + 256 pp. Illus. $3.50. Dodd, Mead, New York. 1953.

Life of the Past: An Introduction to Paleontology. George Gaylord Simpson. xii + 198 pp. Illus. $4.00. Yale University Press, New Haven, Conn. 1953.

Films in Psychiatry, Psychology, and Mental Health. Adolf Nichtenhauser, Marie L. Coleman, and David S. Ruhe. 269 pp. + plates. $6.00. Health Education Council, New York. 1953.

Oil in the Soviet Union. Heinrich Hassmann. Trans. by Alfred M. Leeston. xvi + 173 pp. + maps. $3.75. Princeton University Press, Princeton, N. J. 1953.

Introduction to Electric Theory. R. G. Fowler. xii + 390 pp. Illus. $7.50. Addison-Wesley, Cambridge, Mass. 1953.

Human Embryology. 2nd ed. Bradley M. Patten. xvii + 798 pp. Illus. Blakiston, New York and Toronto. 1953.

Wild Flowers of America. Based on paintings by Mary Vaux Walcott as published by the Smithsonian Institution of Washington, with additional paintings by Dorothy Falcon Platt. H. W. Rickett, Ed. 71 pp. + 400 color plates. $10.00. Crown, New York. 1953.

Science and Fruit. T. Wallace and R. W. Marsh, Eds. Commemorating the Jubilee of the Long Ashton Research Station 1903–1953. xiii + 308 pp. Illus. + plates. 30/ ($4.50). University of Bristol, Bristol, Eng. 1953.

The Logic of Modern Science. J. R. Kantor. xvi + 359 pp. $6.00. Principia Press, Bloomington and Evanston, Ill. 1953.

Method and Theory in Experimental Psychology. Charles E. Osgood. vi + 800 pp. Illus. $10.00. Oxford University Press, New York. 1953.

Plant Diseases. The Yearbook of Agriculture, 1953. xviii + 940 pp. Illus. + plates in color. $2.50. United States Department of Agriculture, Washington, D. C. 1953.

The Way of the World. George H. T. Kimble. x + 123 pp. $2.50. George Grady Press, New York. 1953.

Science News, 29. A. W. Haslett, Ed. 128 pp. Illus. + plates. $.50. Penguin Books, Baltimore, Md. 1953.

Science in Progress. 8th series. George A. Baitsell, Ed. xiv + 285 pp. Illus. $6.00. Yale University Press, New Haven, Conn. 1953.

The Ant World. Derek Wragge Morley. 191 pp. + plates. $.50. Penguin Books, Baltimore, Md. 1953.

Astrology and Alchemy: Two Fossil Sciences. M Graubard. xi + 382 pp. Illus. $5.00. Philosophical brary, New York. 1953.

Standard Methods of Clinical Chemistry, Vol. I. By American Association of Clinical Chemists, Miri Reiner, Ed. xii + 142 pp. $4.50. Academic Press, N York. 1953.

Readings in the Philosophy of Science. Herbert Feigl a May Brodbeck, Eds. ix + 811 pp. Appleton-Centu Crofts, New York. 1953.

A Laboratory Manual of Experiments in Physics. 6th Leonard Rose Ingersoll, Miles Jay Martin, and Th dore Alton Rouse. xi + 286 pp. Illus. $4.00. McGra Hill, New York and London. 1953.

A Manual for the Organic Chemistry Laboratory. Le C. Anderson and Werner E. Bachmann. xvi + 164 Wiley, New York; Chapman & Hall, London. 19

Glacier Variations and Climatic Fluctuations. H. W: Ahlmann. (Bowman Memorial Lectures.) v + 51 Illus. + plates. American Geographical Society, N York. 1953.

Practical Taxidermy: A Working Guide. John W. Moy vii + 126 pp. Illus. $3.00. Ronald Press, New Yo 1953.

Machines that Built America. Roger Burlingame. 214 $3.50. Harcourt, Brace, New York. 1953.

Medical Research. F. H. K. Green and Gordon Cov Eds. (Medical History of the Second World Wa xvi + 387 pp. 40s. Her Majesty's Stationery Offi London. 1953.

Atomic Weapons in Land Combat. G. C. Reinhardt a W. R. Kinter. 182 pp. Illus. $3.95. Military Serv Publ., Harrisburg, Pa. 1953.

A Tree is a Tree. King Vidor. 315 pp. + plates. $3. Harcourt, Brace, New York. 1953.

The Tools of Social Science. John Madge. x + 308 Longmans, Green, London and New York. 1953.

Thorstein Veblen: A Critical Interpretation. Da Riesman. xv + 221 pp. $3.00. Scribner's, New York a London. 1953.

Your Trip into Space. Lynn Poole. 224 pp. Illus. $2. McGraw-Hill, New York and London. 1953.

Design for Decision. Irwin D. J. Bross. viii + 276 $4.25. Macmillan, New York. 1953.

The Structure of Human Personality. H. J. Eysen xix + 348 pp. Illus. $5.75. Methuen, London; Wil New York. 1953.

Communication: From Cave Writing to Television. Ju Forsyth Batchelor. vi + 116 pp. Illus. $2.50. Harco Brace, New York. 1953.

The Mammals of Minnesota. Harvey L. Gunderson a James R. Beer. xii + 190 pp. Illus. Paper: $2. cloth: $3.50. University of Minnesota Press, Minne olis. 1953.

Reptiles and Amphibians. A guide to familiar Am can species. 157 pp. Illus. $1.50. Simon and Schus New York. 1953.

Atoms and Energy. H. S. W. Massey. 174 pp. Illus. $3. British Book Centre, New York. 1953.

Living with a Disability. Howard A. Rusk and Eug J. Taylor. 207 pp. Illus. $3.50. Blakiston, New Yo 1953.

Flora of West Virginia, Part II. P. D. Strausbaugh a Earl L. Core. 296 pp. Illus. $1.00. West Virginia U versity, Morgantown, W. Va. 1953.

Meetings

Dec. 26–31. AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE. Boston, Mass.

Dec. 27–30. American Astronomical Society. Nashville, Tenn.

Dec. 27–30. American Statistical Association. Washington, D. C.

Dec. 27–30. Institute of Mathematical Statistics. Washington, D. C.

Dec. 28–30. American Anthropological Association (Annual). Tucson, Ariz.

Dec. 28–30. American Philosophical Association. Rochester, N. Y.

Dec. 28–30. Archaeological Institute of America. New York, N. Y.

Dec. 28–30. Western Society of Naturalists (Winter). Los Angeles, Calif.

Dec. 28–31. American Mathematical Society. Baltimore, Md.

Dec. 29–30. Oregon Academy of Science (Annual). Portland, Ore.

Jan. 2–8. Indian Science Congress. Hyderabad, India.

Jan. 4–5. Conference on High Energy Nuclear Physics (4th Annual). Rochester, N. Y.

Jan. 4–5. The Mathematical Association (Annual). London, England.

Jan. 11–13. Southern Weed Conference. Memphis, Tenn.

Jan. 13. Astronomical Society of the Pacific (Annual). San Francisco, Calif.

Jan. 13–14. American Pomological Society (Annual). Indianapolis, Ind.

Jan. 13–15. American Society of Photogrammetry (Annual). Washington, D. C.

Jan. 13–20. Australian and New Zealand Association for the Advancement of Science. Canberra, Australia.

Jan. 14. American Genetic Association (Annual Business). Washington, D. C.

Jan. 18–22. American Institute of Electrical Engineers (Winter general). New York, N. Y.

Jan. 18–23. Pakistan Science Conference (6th Annual). Karachi, Pakistan.

Jan. 23–28. American Meteorological Society. New York, N. Y.

Jan. 25–27. American Society of Heating and Ventilating Engineers (60th Annual). Houston, Tex.

Jan. 25–29. Institute of the Aeronautical Sciences (Annual). New York, N. Y.

Jan. 27–29. Conference on Radio Astronomy, Carnegie Institution and National Science Foundation. Washington, D. C.

Jan. 27–29. International Technical Conference, Society of Plastic Engineers. Toronto, Canada.

Jan. 28. American Federation for Clinical Research (Annual). Portland, Ore.

Jan. 28–30. American Association of Physics Teachers. New York, N. Y.

Jan. 29–30. American Geophysical Union. Los Angeles, Calif.

Jan. 29–30. Conference on Protein Metabolism (10th). Rutgers Univ., New Brunswick, N. J.

Jan. 29–30. Western Society for Clinical Research (7th Annual). Portland, Ore.